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Media Asset Management in Broadcasting

New approaches to enable the effective management of physical
resources and media objects

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Resumo

Tradicionalmente, os arquivos de televisão têm sido considerados o último elemento numa cadeia de produção complexa. Limitações em termos de recursos financeiros, de pessoal e de tempo, fizeram com que a reutilização dos arquivos de televisão fosse difícil. Além disso, os requisitos técnicos para manter filmes e cassetes em ambientes estabilizados, impedem a utilização dos arquivos como ferramenta de trabalho diário.

No entanto, a importância dos arquivos de televisão tem vindo a aumentar não só porque lhes é reconhecido um valor cultural importante, mas também porque é possível prever um retorno financeiro considerável. Este cenário fez com que os detentores de arquivos deixassem de os considerar apenas como um lugar conveniente onde armazenar material, para passarem a vê-los como uma fonte quase inesgotável de conteúdos reutilizáveis.

Esta tese aborda o projecto de sistemas de gestão de arquivos audiovisuais de televisão. Para além da arquitectura e componentes do sistema, o trabalho apresentado discute o problema da instalação e utilização destes sistemas em ambientes reais apresentando propostas que deverão facilitar esta tarefa.

Numa primeira tentativa de responder à necessidade urgente de definir mecanismos que reduzam a manipulação de cassetes, o trabalho intensivo, a distribuição errada de material e que permitam uma anotação mais rápida dos conteúdos, fornecendo também as bases técnicas para a implementação de comércio electrónico e reutilização de material, esta tese discute arquitecturas, componentes e funcionalidades de um sistema de gestão de arquivos audiovisuais. Uma proposta baseada em tecnologias da informação é apresentada juntamente com um protótipo desenvolvido e instalado num ambiente de utilização real. Este protótipo permite a validação das ideias principais e serve de base para outras propostas que pretendem implementar uma gestão efectiva dos componentes e recursos do sistema.

Para abordar a questão da gestão de recursos, propõe-se uma arquitectura de dois níveis. A camada inferior, baseada numa plataforma composta por um conjunto de interfaces e protocolos, actua ao nível do software e hardware e permite a integração de aplicações e produtos heterogéneos. A camada superior introduz o conceito de *Business Driven Management* aplicado aos arquivos de televisão de grande dimensão e define uma ontologia que actua como plataforma de integração de metadados e fornece uma interface simples para a implementação de ferramentas de apoio à decisão de alto nível.

Abstract

Traditionally, television archives have been considered the last link in a long and complex production chain. Limitations in financial resources, manpower and time, made re-use of television archives quite difficult. Moreover, the physical requirements of maintaining film and older tape formats in stabilized environments prevents the use of an archive as an every-day production tool for busy broadcasters.

However, the importance of archives has been growing during the last years as they not only have a recognised huge cultural value but also because an economic revenue can be foreseen. This has led broadcasters to take a much closer interest in their archives: no longer is the archive a convenient place in which to store the tapes used for production, but, on the contrary, it is a source of material which can be recycled.

This thesis addresses the design of Media Asset Management Systems in Broadcasting. Besides system architecture and components, the work discusses the problems of system deployment and management in real world conditions and presents proposals that are expected to facilitate this task.

In a first attempt to answer the need to urgently define mechanisms for reducing tape handling, intensive staff work, distribution of unwanted media as well as to enable faster documentation and to provide the technical basis for electronic commerce and re-purpose of archive material, the thesis discusses architectures, components and functionalities of a Digital Media Asset Management system. A proposal based on IT technologies is presented together with a prototype, developed and deployed in a real world environment. This prototype, which enables the validation of the main ideas, acts also as the background for further proposals towards the effective management of system components and resources.

To address the problem of resource management, a two-level management architecture is proposed. The lower layer, based on a Framework composed by a set of standard interfaces and protocols, acts at the software and hardware level and enables the integration of

heterogenous media applications and products. The upper layer introduces the concept of *Business Driven Management* of broadcasting archives and defines an ontology that acts as a metadata integration platform providing a new tool for decision makers.

Résumé

Traditionnellement, les archives de télévision ont été considérées comme le dernier maillon d'une longue et complexe chaîne de production. La pénurie de ressources financières, de personnel et de temps, a rendu la réutilisation des archives de télévision très difficile. De plus, les conditions matérielles nécessaires pour préserver des films et bandes magnétiques dans un environnement stable empêche l'utilisation de l'archive comme un outil de production systématique pour les diffuseurs.

Toutefois, l'importance des archives n'a cessé de croître au cours des dernières années, car elles sont non seulement reconnues comme étant d'une immense valeur culturelle mais aussi économique, car un revenu économique est envisageable. Ceci a conduit les diffuseurs à s'intéresser de plus près à leurs archives : les archives ne sont plus (seulement) un endroit où stocker les enregistrements utilisés pour la production, mais, au contraire, ils sont une source de matières qui peuvent être recyclées.

Cette thèse adresse la conception des systèmes de gestion d'archives pour des diffuseurs de télévision. Le travail aborde, en plus de l'architecture des systèmes et des composants, les problèmes d'implémentation et de gestion du système dans les conditions du monde réel et présente des propositions qui devraient faciliter cette tâche.

Dans le but de répondre à l'urgente nécessité de définir des mécanismes pour réduire la manipulation de bandes magnétiques, le besoin en ressources humaines, la distribution de médias non désirés, ainsi que pour permettre d'effectuer plus rapidement la documentation et de fournir la base technique pour le commerce électronique et la réutilisation du matériel d'archive, cette thèse évoque les architectures, les composants et les fonctionnalités d'un système de gestion des document audiovisuel. Une proposition basée sur les technologies de l'information est présentée avec un prototype, mis au point et déployé dans un environnement réel. Ce prototype, qui permet la validation des idées principales, agi aussi comme arrière-plan pour de nouvelles propositions en vue de la gestion efficace

des composants et des ressources du système.

Pour régler le problème de la gestion des ressources, une architecture de gestion à deux niveaux est proposé. La couche inférieure, en s'appuyant sur un cadre composé par un ensemble de protocoles et d'interfaces standard, agit au niveau des logiciels et de l'équipement et permet l'intégration d'applications de médias et de produits hétérogènes. La couche supérieure introduit la notion de *Business Driven Management* des archives de télévision, et définit une ontologie qui agit comme une plate-forme d'intégration de métadonnées fournissant un nouvel outil pour le procès de décision.

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Glossary

AMIA	Association of Moving Image Archivists
ANSI	American National Standards Institute
ASSET	Architectural Solutions for Services Enhancing digital Television
ATM	Asynchronous Transfer Mode
B2C	Business-to-Consumer
B2B	Business-to-Business
BBC	British Broadcasting Corporation
BDIM	Business Driven IT Management
BiM	Binary format for MPEG-7
BNF	Backus-Naur Form
CIM	Common Information Model
CIMOM	CIM Object Manager
CMIP	Common Management Information Protocol
CORBA	Common Object Request Broker Architecture
CM	Content Management
CP	Content Package
D	Descriptor
DAS	Direct Attach Storage
Ds	Descriptors
DS	Description Scheme
DAM	Digital Asset Management
DCM	Digital Content Management
DCMES	Dublin Core Metadata Element Set
DCMI	Dublin Core Metadata Initiative
DDL	Description Definition Language

DMP	Drive Management Protocol
DMS	Descriptive Metadata Scheme
DMTF	Distributed Management Task Force
DOM	Document Object Model
DRM	Digital Rights Management
DSM-CC	Digital Storage Media Command and Control
DVB	Digital Video Broadcast
EAV	End of Active Video
EBDO	Elementary Broadcast Device Object
EBNF	Extended Backus-Naur Format
EBU	European Broadcasting Union
EDL	Edit Decision List
EIT	Event Information Table
EPG	Electronic Programme Guide
ETSI	European Telecommunications Standards Institute
FC	Fibre Channel
FCIP	Fibre Channel over IP
FEC	Forward Error Correction
FIAF/IFTA	Fédération Internationale des Archives du Film International Federation of Film Archives
IASA	International Association of Sound and Audiovisual Archives
IBC	International Broadcasting Convention
ICA	International Council on Archives
IDL	Interface Definition Language
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
iFCP	Internet Fibre Channel Protocol
IIOP	Internet Inter-ORB Protocol
INA	Institut National de l'Audiovisuel (France)
IP	Internet Protocol
IPv6	IP version 6
IPR	Intellectual Property Rights
iSCSI	SCSI over IP

ISDN	Integrated Services Digital Network
ISO/IEC	International Standards Organization / International Electrotechnical Commission
IT	Information Technologies
ITU	International Telecommunications Union
JMS	Java Message Service
JPEG	Joint Photographic Experts Group
KLV	Key-Length-Value
HTTP	HyperText Markup Language
HTML	HyperText Transfer Protocol
LAN	Local Area Network
LMP	Library Management Protocol
MAM	Media Asset Management
MAN	Media Area Network
MDD	Metadata Dictionary
MDL	Minimum Data List
MDS	Multimedia Description Scheme
MIB	Management Information Base
MMIP	Media Manager Interchange Protocol
MMP	Media Management Protocol
MMS	Media Management Systems
MOF	Managed Object Format
MOS	Media Object Server Media Object Server Communication Protocol
MPEG	Motion Pictures Experts Group
MXF	Material Exchange Format
NAA	Netherlands Audiovisuel Archief
NAS	Network Attach Storage
NCS	Newsroom Computer Systems
NDCP	Network Device Control Protocol
NFS	Network File System
NLE	Non Linear Editing
ODBC	Open Data Base Connectivity
OMT	Object Modelling Techniques

OO	Object Oriented
ORB	Object Request Broker
ORF	Osterreichischer Rundfunk
OSI	Open Systems Interconnection
OWL	Web Ontology Language
OWL-S	Semantic Markup for Web Services
PDA	Personal Digital Assistant
RAI	Radio Televisione Italiana
RDD	Right Data Dictionary
RDF	Resource Description Framework
REL	Right Expression Language
RMI	Remote Method Invocation
RPC	Remote Procedure Call
RTP	Radio Televisão Portuguesa
SAN	Storage Area Network
SAV	Start of Active Video
SAX	Simple API for XML
SCSI	Small Computer Systems Interface
SDL	Specification and Description Language
SDI	Serial Digital Interface
SDT	Service Description Table
SDTI	Serial Data Transport Interface
SDTI-CP	SDTI Content Package
SIT	Selection Information Table
SMI	Structure of Management Information
SMPTE	Society of Motion Picture and Television Engineers
SNIA	Storage Networking Industry Association
SNMP	Simple Network Management Protocol
SOAP	Simple Object Access Protocol
SRM	Storage Resource Management
SSAIP	Session Security, Authentication, Initialization Protocol
SVT	Swedish TV Archive
SWR	Sudwestfunk Suddeutscher Rundfunk
SWRL	Semantic Web Rule Language

TeM	Textual format for MPEG-7
TCP	Transmission Control Protocol
TINA	Telecommunications Information Networking Architecture
UMID	Unique Material Identifier
UML	Unified Modelling Language
VACP	Video Archive Control Protocol
VDCP	Video Disk Control Protocol
VHS	Video Home System
VTR	Video Tape Recorder
VCR	Video Cassette Recorder
W3C	World Wide Web Consortium
WBEM	Web Based Enterprise Management
WDR	Westdeutscher Rundfunk (Germany)
YLE	Finnish Radio
XML	Extensible Markup Language
XMLs	XML Schema
XPath	XML Path Language
XSL	Extensible Stylesheet Language
XSLT	XSL Transformations

Chapter 1

Introduction

This thesis addresses the design of Media Asset Management Systems in Broadcasting. Besides system architecture and components, the work discusses the problems of system resources management and proposes an approach based on on-going research in the area of semantic Web. This chapter presents an overview of the research scope and objectives, the background and motivation of the author to conduct this research and defines the meaning of some of the concepts used through out the thesis.

1.1 Background

The evolution of Television towards the digital domain is opening new opportunities but also new challenges both to manufacturers, users and system managers. The digitisation of the video signals will enable the integration and harmonisation of technologies from different worlds such as the Computer, Telecommunications and Television areas. In a Broadcaster environment this will imply drastic changes not only in the equipment available but also on the working methods. Some examples of this integration are already starting to happen with the use of tools and systems based on Personal Computers as well as the interconnection of computer networks and telecommunication systems as a support for the modern television studios.

The evolution on telecommunications suggests that all the production process in a future Broadcaster environment will depend on the access to remote services distributed among large geographical areas implying, then, huge changes in the studio architectures and in the process of interchanging television material. Even the concept of television

material will change as it will be regarded as the collection of audio and video material, as well as associated metadata, all multiplexed and associated in a bit stream.

This integration will transform management of information access and flow in an important and difficult task: it is necessary to define formats and means for information exchange between different systems, as well as methods that enable an efficient process of classification and searching of this video information.

System networking and data transmission have been seen as important requirements for the effective work in the broadcast industry. The real-time, synchronous transmission and large bandwidth requirements in the professional environment led to the definition of specific standards such as SDTI (Serial Data Transport Interface) and Fibre Channel as the preferred interfaces and transport mechanisms. Meanwhile, the evolution in the general-purpose IT networks towards high speed, low cost and with QoS guarantee, made them suitable for content streaming and competitive with the traditional broadcast solutions. The evolution of IP to a de-facto standard for data communication and the success of HTTP based applications led to the large implementation of data networking within companies premises. The evolution of these communication platforms to all the areas of activity within a Broadcaster started to be regarded as the direction for evolution.

Meanwhile, the advent of new diffusion networks as cable, digital television, UMTS and Internet, with different characteristics and requirements, make the re-use and re-purpose of material an important mean to lower the costs of all the production chain. Television archives are starting to be considered essential in this new scenario of a Broadcaster activity and moving to a central part of the broadcasting workflow.

This context of technology and workflow evolution led to the increase of interest of the R&D community towards the definition of architectures and tools that would enable integrated solutions in a Broadcaster archive entirely based on generic IT and open standards. The concept of producing once for multiple platforms and of re-using content for multiple productions brings the archive to the core of a Broadcaster operation.

1.2 Scope and Relevance of the theme

Research in the area of Media Asset Management has been gaining importance in the scenario of the evolution from analogue to digital in the television world which 1) enables the integration and harmonisation of the technological advances that have been happening in the Computer and Telecommunications areas and 2) makes the archive a central part

of a Broadcaster.

The new concepts coming from the IT area enable the introduction of new features in a television plant but raise also some significant problems. Examples of problems are the multiplicity of definitions of storage systems' architectures, the diversity of metadata models and the number of proprietary systems for archiving. This scenario delayed decision makers resolution as any solution would have to be validated in the long term.

Research on MAM is carried by a small community which has started to obtain results in the last years. Advances have been presented mostly in very oriented conferences as *SMPTE Technical Conference*, *IBC Conference* and *NAB Broadcast Engineering Conference*, which aggregate contributions from universities, broadcasters and manufacturers from all over the world. *SMPTE Motion Imaging Journal* and *EBU Technical Review* are also good sources of information for newcomers since they regularly incorporate interesting papers on topics related to the theme. Articles on MAM aspects appear rarely in more general conferences or journals. However, some particular aspects of the problem have been treated in special journal numbers or thematic workshops in generic Communication and Multimedia conferences.

All the evolution in this area has required jointed efforts and the cooperation on the normalization of different aspects by standard institutions. The European Broadcast Union (EBU), together with SMPTE (Society of Motion Picture and Television Engineers), has been working in a direction of harmonising formats for the interchange of programme material in a digital television (DVB and ATSC) environment [EBU/SMPTE 1998]. Defining generic models, architectures and functionalities for MAM has also been object of study in the research community and in Broadcasters' organisations as the Future Television Archive (FTA) project within the EBU Production Technology Management Committee [EBU 2001a].

At the same time, lots of effort has been put in different projects and initiatives for the definition of metadata models: ISO-MPEG7 proposes a generic multimedia information description schema [ISO/IEC 2002a; Martinez et al. 2002], EBU-P/META and SMPTE, in broadcaster environments, have defined metadata exchange schemas [EBU 2007], Metadata Dictionaries [SMPTE 2001a,c] and formats for uniquely identifying material [SMPTE 2004b], while Dublin Core [DCMI] has been working on a larger range of domains.

Being, by nature, systems which are distributed throughout the organisation, aspects on distributed models have also been object of research for MAM. Some experiences have

been done for the creation of a multimedia middleware layer for the management of networked multimedia systems. The use of CORBA (Common Object Request Broker Architecture) [OMG 2002] and, more recently, Web Services [W3C 2002] are being tested in some case studies.

Associating metadata to content, using standard IT networks and workstations instead of the expensive equipment usually required in a traditional broadcasting environment, defining an architecture composed by a set of different archives, with different accessibility and quality, including Internet based access, as well as defining a data model for the metadata, were the first steps towards the development of prototypes. VIDION (Video Digital On Line) project, which is detailed later, is an example of a research effort to design a solution to enable the integration of the acquisition, production, broadcasting and archiving operations in the broadcasting chain, using as much as possible IT technologies.

One of the open research issues is the definition of methods that will allow the management of system resources in a MAM environment. Effective deployment of such a system in a real environment requires the development of those management platforms that contribute to efficient system usage by all the players involved in the TV archive — from the creative people to the technical and administrative manager. Those resource management aspects have not been, up to now, the main concern of researchers and system developers but are a critical issue for the successful exploitation of this kind of systems.

The work presented in these thesis enlarges the concept of metadata as it has to be regarded not only as data describing audiovisual content but also as data describing system resources and policies for global resource management. The approach exploits concepts and technologies under development in organisms such as DMTF (Distributed Management Task Force), SNIA (Storage Networking Industry Association), IEEE (Institute of Electrical and Electronics Engineers) and W3C (World Wide Web Consortium) and extends them to the study case of a Broadcaster audiovisual archive. The aim is trying to make the solution independent, as much as possible, from the supporting technologies, so that it can be the motivation for Broadcasters to adopt a digital solutions for archiving.

1.2.1 Motivation

The first research work in which the author participated was a project financed by the department of R&D of Portugal Telecom (PT), the Portuguese Telecommunications Operator, which aimed at developing a service for remote access to photographic information.

By that time, ISDN was just being introduced in Europe and Pan-European tests where been conducted. The work developed within this project allowed the participation in the ETSI working groups for the standardisation of what was called ‘Alpha-Photographic Videotex Service’: end-to-end protocols, APIs for ISDN adapters, terminal equipment and data structure where still not defined. ISO/IEC JPEG and MPEG groups where at that time working on the definition of algorithms for image and video compression and the work on this project enabled also the participation in technical meetings of this organisation. Although the prototype developed did never get to be a product (as the first experiences on HTML/HTTP based services, in early 1990s, got a tremendous success and Internet community won the battle against telecommunication operators), it was essential for the definition of future working area: multimedia telecommunication services.

The participation on ACTS project SCREEN (Service Creation Engineering Environment) which aimed at defining a methodology and producing a set of tools for the creation of telecom services using emerging technologies and concepts such as OMT, SDL, TINA and CORBA, enabled the first contact with some technologies that later proved to be essential for the development of any networked service. The job of the author was to collaborate on the definition of the SCREEN proposed methodology and on the validation of the results through the implementation of a field trial. For that purpose, and joining the effort of the participation on the ESPRIT DELOS project, she worked on the definition and development of a Digital Library trial, which involved building an information service and was intended to demonstrate the creation of a distributed repository and retrieval service for multimedia information. DELOS project, with an heterogeneous list of partners, enabled the contact with possible end-users and multimedia asset managers, providing important real-world information. SCREEN provided the author important knowledge on emerging technologies and techniques from the IT world, which gave her an innovative view on the developing of telecommunication software.

Later on, within an INESC effort to establish R&D projects in the area of Digital Television, the author become the technical coordinator of VIDION – Video Digital On-Line, a R&D project funded by PRAXIS XXI and having RTP (Portuguese Public Television Broadcaster) as a partner. VIDION main goal consisted in proposing a strategy for the evolution towards the digital domain of the complete RTP audio-visual archive. The project should develop a small-scale prototype to be used by the News Service. Although

this was a Portuguese project, contacts with BBC enabled an exchange of ideas with another important broadcast operator. This experience was enlarged by a one month stay in BBC-R&D labs in Kingswood Warren, England, that enabled the exchange of ideas, the participation in brainstorm meetings, the contact with other ongoing projects and the access to privileged information.

Over the years, BBC-R&D and its forerunners have been recognised by their peers as making major contributions to the world of broadcasting. One of the most tangible measures of this recognition, besides the number of published work and the participation in several international R&D consortiums, is the variety and quality of awards that this BBC Department has received. By developing research in a set of areas that spread from the development of new systems to bring the efficiency of new technology into the production environment, new communications systems and methods of broadcasting to the home, new Internet delivery techniques, the creative use of digital video recording and the development of compression and streaming formats for the BBC's content, it is an excellent place for a researcher to get in touch with plenty of different areas all related to broadcasting.

By that time, BBC was also looking for solutions for the management of their assets spread over a set of different towns. The *Natural History Archive*, due to its smaller dimensions, was considered a suitable test bed where to try out new developments. A VIDION prototype was installed in the R&D facilities and used to test some concepts and solutions.

Besides this valuable experience in the research labs, visits to different departments of BBC operational areas in London made available precious inputs to the ongoing and future research. A visit to the *BBC Central Archives* provided extended input to be used in this thesis and re-enforced our initial ideas. Furthermore, ideas for future work came out also from the analysis and consolidation of the information collected. The *BBC Television Centre*, where the *News24* programme was produced, was also an excellent place of visit: new technologies were being tested on a news production system and the need for new archive policies became evident.

While VIDION project was still running, a quite different challenge became apparent: while the participation in these projects enabled the development of scientific work in the area of multimedia telecommunication services, the author had no experience on participating in initiatives that would enable commercial exploitation of R&D results. The

challenge of this new initiative that would provide the means to deploy a prototype in a real production workflow opened new opportunities for further research work: the resource management aspects in a MAM that are critical for the development of archiving applications to be deployed in real working environments.

The following participation in the IST ASSET (Architectural Solutions for Services Enhancing digital Television) proved that this approach was the right one and that the research community was starting to become interested in these new aspects of resource management.

Given the author experience in a broad range not easily covered in current research, it was decided not to focus just on a particular aspect of the work developed but to provide a large overview of some of the aspects covered.

1.3 Objectives of the Thesis

This thesis main objective is to propose strategies that enable the effective deployment of complex networked audiovisual archives in Broadcaster environments.

At a more detailed level, the thesis presents and discusses some of the technology and process-related questions that are likely to appear with the introduction of digital media in the processing chain inside a Broadcaster facility and, more precisely, in the archive premises. More specifically, the research has the following goals: *1)* to understand the complexity of the definition and deployment of media asset management systems in Broadcaster environments; *2)* to define appropriate architectures that facilitate the use of valuable footage available in the archive; *3)* to provide an integrated view of the technologies and research areas involved; *4)* to formulate a methodology that, by aggregating different scientific and technologic topics, facilitates the integrated management of physical resources and content from an upper business oriented view rather than from a technical viewpoint.

Due to the complexity of the problem, this work doesn't follow the traditional dissertation format of concentrating on a certain, well-defined problem in isolation from its broader context. The results presented in this document span a broad range of topics raising the focal point from isolated details to the system and its interrelations. As research integrating different business and technology aspects is the area of Media Asset Management is still in its infancy, the work presented in this thesis is intended to be an early trailblazer in the area, for more detailed approaches to follow.

1.4 Terminology

The introduction of digital systems and networks in the Broadcaster environments led to the need of defining or clarifying some concepts and terms so that a unique meaning is used. ITU [ITU 1998] and EBU/SMPTE Task Force [EBU/SMPTE 1998] proposed the following use of the words ‘Essence’, ‘Metadata’ and ‘Content’:

Essence is the programme material itself. Essence includes all data that represents pictures, sound and text; types of Essence include Video, Audio, Graphics, Still Images, Text, and other sensor data as needed by each application. Essence may be encoded or compressed in whatever way is appropriate and is typically structured in packets, blocks, frames or other groups. Essence typically has the characteristic of a stream, with sequential access whether stored on a file device or streaming device. Stream data will normally be presented in a sequential time dependent manner. Essence stored on a file storage device can be randomly accessible. Essence not having the characteristic of a stream (e.g. graphics, captions, text) may still be presented in a sequential time dependent manner.

Metadata is any information related to essence or describing essence, but not the essence itself and is broadly defined as ‘data about data’. The number of distinct varieties of Metadata is potentially limitless. To assist with describing requirements and behavior, Metadata is divided into several categories, depending upon its purpose.

Content is the combination of Essence and any associated Metadata.

Although ‘Essence’, as defined above, includes all type of media, it will be used in this thesis mainly to mean video data and its associated audio. When the context provides a clear meaning, the term ‘Content’ will also be used to denote video material, as this is the most common term used in literature.

The terms ‘Content Management’ (CM), ‘Media Asset Management’ (MAM), ‘Digital Asset Management’ (DAM) or ‘Digital Content Management’(DCM) are terms with the same meaning [Gascon 2002] and are defined in this context as:

Media Asset Management is the set of processes, systems and tools needed to manage a piece of Essence and its associated Metadata and to maintain the relations between different versions of the same Content. The

main purpose is to enable the identification, capture, digitisation, storage, cataloguing and the efficient access/retrieval to collections of film and video footage, stills, text and audio that have value for re-purposing within organisations [EBU 2001a].

Content Management is not only applicable to the archive but spreads over production and broadcasting. In the context of this thesis, this terms will however be used to refer to the processes that have impact on television archives.

Metadata interoperability is an important issue in the context of MAM. In this thesis, the meaning of ‘Metadata Interoperability’ follows the definition provided by [Oltmans 2001]:

Metadata interoperability It should be possible to unambiguously interchange between metadata schemes (in the textual and binary representation formats) such that components share similar meanings for all compliant parsers/decoders.

Metadata schemes should contribute to interoperability by defining the normative specification of their components in terms of elements from other metadata schemes. This also implies that one particular system could use different sorts of metadata at the same time, without confusion about their respective meanings or intentions of use.

1.5 System Deployment Guidelines

The design of Broadcast CM systems is not a straight forward but a complex task. Conflicting requirements, such as 1) the need for flexible solutions that respond to different departments requirements; 2) initial investment into system hardware and software without any immediate profits; and 3) no de-facto standard for implementing the whole solution, requires the adoption of a policy of phased development and integration of modules.

The development of a MAM system may be generically described in terms of the following tasks [SCREEN 1997]:

- i. Requirements Gathering and Analysis during which the developer assembles and documents the requirements on the service in co-operation with the user;

- ii. Service Analysis during which the developer defines what the service is to do from an implementation point of view;
- iii. Service Design during which the developer defines the interface and behaviour of the service in accordance with implementation constraints;
- iv. Validation and Simulation during which the developer verifies that the defined behaviour is in accordance with the requirements;
- v. Deployment during which an implementation is generated from the design.

This approach to service creation involves five phases, which are performed iteratively. Thus, the output from one phase becomes the input for later phases, while output from later phases can become input for a new iteration of an earlier phase. Feedback to previous phases is an essential aspect because later phases may bring to light inconsistencies and erroneous assumptions made in previous phases.

Sometimes, work on *Requirements Gathering* and *Service Analysis* proves to be more efficient if developed together. The main reason for this is the difficulty of end-users to state their needs and of developers to understand the whole problem.

EBU recommends [EBU 2001a] that *Deployment* within a large broadcast organisation shall be carried out in different phases until normal operation is achieved: 1) for the first prototype testing, only a project group set up for that purpose will be used; 2) the next pilot installation shall allow access from 50 users; 3) this prototype shall then be continuously extended to handle 400 users.

The work presented in this thesis went through all these defined phases. By addressing a problem that requires the interaction of people from different areas and by dealing with a set of different scientific areas usually scattered among isolated teams, the research process was quite iterative and new requirements and approaches were defined after the completion of a partial phase. Although this delayed the whole process, partial outcomes made available valuable inputs to the next research topic. Deployment of the system was only partially achieved in the light of the EBU recommendations. Nevertheless, given the complexity and the broad scope of the work, the level of real world implementation can be considered adequate for the validation of the proposals.

1.6 Outline of the Thesis

This thesis is organised in 8 chapters and 2 appendixes. In Chapter 1, the author introduces the scope and relevance of the work as well as the motivation for developing the conducted research. The main goals are also outlined.

Chapter 2 provides background information on the current situation on Broadcast Archives. Information on operational aspects, holdings and usage of some of the most important European Broadcasters is presented.

Chapter 3 provides an overview of the main recommendations and initiatives developed by user and standardisation organisations towards the definition of metadata schemas that are relevant to broadcasting.

Besides providing media enhancement through a set of normalised descriptors, supporting the main goals of a media asset requires the definition of architectures that enable the integration of several devices. An overview of the different approaches and technologies concerning the deployment of media assets in a networked environment is presented in Chapter 4. Two main lines are described: the current solutions provided by broadcasting equipment manufacturers and the IT solutions under development in the area of *Storage Networking*.

Chapter 5 presents the architecture of a MAM system developed within the research context described in the previous chapters. The main components of the system are introduced and architecture decisions are justified according to the current scenario.

Having as background the proposed model and prototype presented in the previous chapter, Chapter 6 highlights the problems of managing a complex MAM in a scenario of real world deployment. It describes the current approaches being developed by the R&D community and presents a proposal that is expected to facilitate the integration of heterogenous media applications and products by providing a middleware layer that makes specific hardware aspects transparent to the application developer.

After introducing the concept of *Business-Driven IT Management*, Chapter 7 discusses the need of an integrated high-level view of the archive that provides mechanisms for managing assets based on high level decision criteria. A new approach based on a metadata framework that integrates concepts from different technical areas through the use of semantic web languages and technologies is presented.

Finally, Chapter 8 draws a set of conclusions, reviews the main contributions of the thesis and gives some guidelines for future work in this area.

The full documentation of the ontology proposed in Chapter 7 is presented in Appendix A.

Appendix B provides some examples of the VIDION user interfaces.

Chapter 2

Broadcast Archives: characterization of the current situation

This chapter provides an overview of the main problems that Broadcast Archives currently face. Information on operation aspects, holdings and usage of some of the most important European broadcast archives enables the characterisation of the current situation and gives some indication on the challenges MAM builders face in the transition to digital. The implications of moving into digital is outlined. Some of the information consolidated in this chapter turned out relevant for the user requirements analysis and proposed system architecture presented in Chapter 5.

2.1 Introduction

Traditionally, television archives have been considered the last link in a long and complex production chain. Limitations in financial resources, manpower and time made re-use of television archives quite difficult. Moreover, the physical requirements of maintaining film and older tape formats in stabilized environments prevent the use of an archive as an every-day production tool for busy broadcasters.

However, the importance of archives has been growing during the last years as they not only have a recognised huge cultural value but also because an economic revenue can be foreseen. For the public broadcasters, there is even another aspect that has to

be considered: the requirement of providing services under-provided by the market as their mission as public servants. Making their assets available on the Internet could help scholars, researchers, etc., achieving a set of objectives otherwise impossible. This has led broadcasters to take a much closer interest in their archives: no longer is the archive a convenient place in which to store the tapes used for production, but, on the contrary, it is a source of material which can be recycled.

There are many interpretations of the term ‘Archive’, even within a single broadcaster [Peters and Chalmers 1996; Serb 1997]:

- i. to a news department, an archive may hold just last weeks’ news or the last few years’ news including rushes;
- ii. to the central archive department, an archive holds finished programmes that may be retained in a intermediate archive (for a few year before the final selection criteria is applied) or in the final or historical archive. Pre-recorded items may be kept in a different location and sent to archive a few weeks after having been broadcasted. Raw material may also be kept on request;
- iii. to a film library, it contains material nothing less than tens of years old;
- iv. to a department it contains assets focusing on a particular niche area (sports, regional emissions, etc);
- v. to a legal department it means all the TV output that must be kept, for legal reasons, for a predefined period (usually 90 days);

As it can be seen, several islands of media assets coexist containing material that spreads from finished programmes to rushes usually scattered throughout broadcaster facilities or temporary broadcast archives.

Although the material held in a television archive, not including films, cannot date from before the late 1950’s (the emergence of magnetic recording), since then, however, the growth in television archives has been exponential.

Having information spread through a number of different places makes the location of video material (not to take into account shooting scripts, stills, unedited takes, browse-quality extracts, etc.) a difficult task.

The major differences between these systems and other archive applications in the IT world, is the time-scale and volume of television production: the timescale can be measured in tens of years and the number of video tapes already runs into millions.

In contrast with other businesses where the concept of real-time, on-line information sharing and workgroup collaboration is a reality, most video-based businesses — motion pictures, network and local television, advertising, Web content development, video marketers — still rely on manual, linear processes to create video content. While the video editing may be digitised, the development process is typically based on non-digital and/or non-real-time communications. This includes analogue recording and storage, the physical exchange of tapes and hand-written notes.

2.2 Broadcast Archives: Holdings

In TV production, the initial recordings are reduced through a number of editing operations to produce the final finished products. The ratio between the rough footage and the final product, in terms of tape usage, varies between 20 to 1 and 5 to 1. The ratio could even be much higher in the area of news production. A total of 60 minutes of acquired programme material, taken by several camera crews, may be reduced to 15 seconds duration of the final news clip [EBU 2001b].

Not all tapes used are delivered to the archive — some of the tapes used for acquisition recordings are erased, reconditioned and reused within the production process. Nevertheless, TV archives are heavily confronted with a constantly increasing number of tapes that must be stored, preserved and made available for re-use.

A survey [Wright and Williams 2001; Wright 2001] to ten major broadcast archives, that represent an important part of the European broadcasters, found 1 million hours of film and 1.6 million hours of video recordings covering the entire century. This material is spread among a variety of supports as illustrated in Figure 2.1 and Table 2.1 for the video material.

Based on these figures, the total European holdings of broadcast material is estimated by the survey to be probably 10 times larger — 10 million hours of film and 20 million hours of video — and the total world holdings to be at least 50 times larger (50 Million, 100 Million). Another study conducted by UNESCO goes even far beyond and estimates the world audiovisual holdings in 200 million hours, 50 million in Europe.

Also according to the same study, access to this content is usually difficult, or even impossible, to the general public and also to national archives and educational institutions because 1) much of the content is unique (master material that cannot be allowed to circulate), 2) all the material is on ‘professional’ formats (film, broadcast-standard videotape

Table 2.1: Video Items in archive by format

Format	Nr of Items	Format	Nr of Items
2" tapes	198585	D3	286663
1" tapes	935993	Digital Betacam	395099
3/4" Umatic	943446	D5	37000
M2	35500	DVC Pro	19430
Betacam	1986135	DVcam	73
VHS	657510	CD-ROM	37575
D1	1090	DVD-R	496
D2	142549		
<i>Total: 5996644</i>			

that need special players) and 3) most of the content has rights issues. Access is also difficult as most of the material is difficult to locate, requires specialized staff to deal with the journalist and creative personnel requests, and leaves the process of searching the archive and producing the final item as disclosed activities developed even in different locations.

2.3 Legacy Material

Besides access difficulties, there are other factors that prevent legacy material from being used. Most Broadcasters have large archival collections on videotape and film that are endangered due to limited storage material lifetime and machine obsolesce [Wright 2002]:

Deterioration : Approximately $\frac{1}{3}$ of the material has some form of deterioration.

Obsolescence : at least $\frac{2}{3}$ of the material in archives cannot easily be used in its existing form because the medium is too specialised or obsolete to allow easy access.

Fragile media : Roughly $\frac{1}{4}$ of the material cannot be released for access because the media are too easily damaged. Examples are: all film negatives, all film prints except for access by qualified professionals, all shellac and vinyl audio recordings.

Keeping legacy material available for reuse has been a technological and financial challenge.

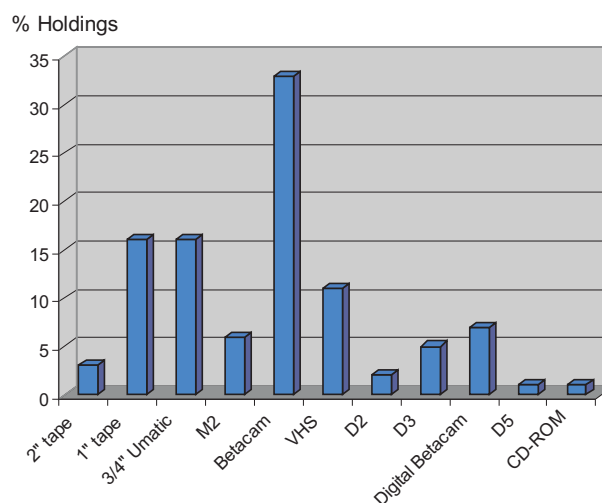


Figure 2.1: Video Items in archive by format

2.3.1 Problems with Tape Handling and Storage

Proper handling of archive material is an essential issue to avoid lost or destruction of important information. EBU, SMPTE, ITU and ANSI provide guidance to technical managers, archivists and technicians for the care, storage, operation, handling and shipping conditions that help maximize life expectancy and interchange performance for television (video) magnetic recording tapes [SMPTE 2000b; EBU 1992, 1974; ITU 1996].

The basic precautions are the same whether the tapes are in formats which have become obsolete, but may contain valuable archive material, or are in the newer formats which, owing to the use of thinner tape supports and much greater information packing densities, are inherently more susceptible to damage than those used earlier.

The recommendations cover such different aspects as temperature and humidity conditions, tape and container characteristics, periodical physical inspections, shelving, etc.

Most of the guidelines refer to all type of tape archives. However, long term archives have special needs concerning temperature and humidity that should be taken into account. SMPTE identifies three different periods for tape storage and the storage conditions according to the required duration [SMPTE 2000b]:

Long-term storage conditions: the storage conditions suitable for preservation of recorded information for a period of greater than ten years.

Medium term storage conditions: the storage conditions suitable for preservation of recorded information from two to ten years.

Short-term storage conditions: the storage conditions suitable for preservation of recorded information for less than two years.

The ideal environment for medium-term storage of videotapes is quite similar to the recommended practice for the operating area. However, the relative humidity must be somewhat lower in the storage area to avoid deterioration. This reduced humidity level, if reproduced in the operating area, might cause static charge in normal tape handling on the recorder. The allowed variations in the temperature and humidity must also be set lower for the archives.

Storage and operating areas should be preferably located close to each other so that climatic cycling can be avoided. Table 2.2 summarizes the environmental conditions that should be observed in the operation areas and for the shipping procedure as well as for medium and long term storage according to SMPTE RP 103 Recommendation [SMPTE 2000b].

Table 2.2: Summary of environmental conditions

	Operations	Storage		Shipping
		Medium Term < 10 years	Long Term > 10 years	
Temperature	17°C to 25°C ± 2°C	15°C to 23°C ± 2°C	12°C to 15°C ± 2°	-20°C to 45°C
Humidity	30% to 70% ± 5%	30% to 40% ± 5%	30% ± 5%	5% to 80%
Temperature gradient/hour	10°C per hour	n/a	n/a	10°C per hour
Humidity gradient/hour	10% per hour	n/a	n/a	10% per hour

Some other advices, concerning archiving magnetic tapes, given by SMPTE RP 103 [SMPTE 2000b] and ITU-R BR.1215 [ITU 1996] are:

- i. every tape in an archive should be physically inspected at least every 3 to 5

years for things as tape playback performance, debris, contaminants, container deterioration, or other problems. This operation can be carried out by inspection of one-third to one-fifth of the archive each year.

- ii. A full length wind/rewind should be completed on each tape at least once in every ten years, preferably during the periodic physical inspection.
- iii. Tape destined for long-term storage should have very few record/playback passes.

Those advices conflict with the normal tasks of a media library and the available technical conditions and resources — checking manually the state of preservation for each tape within a shelf based archive with 250 000 tapes at least every 5 years means [Heitmann 2002, 2000]:

- i. to check approximately 1 000 tapes per week;
- ii. to transport 200 tapes per working day to/from the players;
- iii. to operate the players, check the quality, initiate a dub if necessary.

Access to programme material on film is resource demanding because of several manual operations, some of which are time consuming on expensive equipment. The film itself can also be endangered because of no available copy material and bad storage conditions that reduce the expected usable lifetime.

Similar recommendations on film handling and storage are given by SMPTE RP 131 [SMPTE 2002], ANSI/PIMA IT9.11 [ANSI/PIMA 1998] and EBU Tech 3202 [EBU 1974] as the major archives have large collections of news material from the 1960's and 1970's that are in risk.

2.3.2 Lifetime of Reproduction Equipment

Since the introduction of videotapes for archiving TV programme material, some attention has been put on the need to properly handle tapes. It is commonly accepted that properly archived tapes can last for 20 or 30 years.

However, besides tape longevity, archivists have also to deal with replay equipment lifetime. The total lifetime of a video tape rarely exceeds 25 years including the production period and the manufacturers support after the termination of product availability [EBU 2001b].

Figure 2.2 illustrates the period of utilization of some videotape formats in the Broadcast environment. Although replay capability of a format is sometimes prolonged by the compatible replay of its successor format, it is already very difficult to find equipment for reading some of the oldest formats: 2-inch Quad, 1-inch B, 1-inch C and Umatic are strongly endangered and Betacam, Betacam SP and M-2 formats are expected to be endangered in a near future.

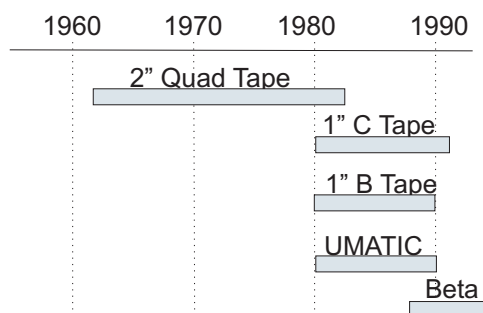


Figure 2.2: Usage of Formats

2.3.3 Security Copy

Access to information in archive is sometimes difficult as tapes are not allowed to circulate: it is estimated [Wright and Williams 2001] that $\frac{1}{3}$ of the videotape has only one master version and the problem is even bigger for audio (over $\frac{1}{2}$) and film holdings (100% in some cases).

Although in most cases the master is not circulated, because there are browse copies as VHS tapes, when the full-quality material is needed, the unique archive item has to be taken off the controlled environment and exposed to a degree of risk.

Even when there are more than one full-quality copy of the same material, it is not guaranteed that one of them is always kept in archive and is not allowed to circulate — the one that ends up being sent depends on the format preferred by the requester.

Restricting circulation to qualified professional users controls the risk of master loss or deterioration but at a cost of low-access, high-risk approach.

2.4 Broadcast Archives: Usage

Broadcast archives are heavily used — 20 to 30% of holdings are circulated every year. However, 75% of the TV circulation is in low quality (VHS tapes), indicating that only one in four items was considered for re-use and the other 3 selected items were rejected after previewing [EBU 2001b; Wright and Williams 2001]. This indicates that a huge amount of tape circulation is due to a wrong selection in the archive catalogue.

It is difficult to verify how many of the high-quality items issued from the archives actually end up being broadcasted (at least in part). The estimate from the archivists is that at least one in four of the broadcast quality items circulated is transmitted, although often just a small clip is used and not the whole material sent from the archive.

Table 2.3 summarises the volume of video material taken into the archives and the circulation every year for some of the major archives in Europe. In most cases, the input represents the most of the TV output and selected non broadcast material (rushes, stockshots). As it can be seen, the volume of material intake into broadcast archives and circulated out of the archives is large.

Table 2.3: Video and Film Archives Holdings, Annual Intake and Circulation [Wright and Williams 2001; Williams 2002]

	YLE	NAA	ORF	INA	RAI
Holdings-Video	350000	260000	800000	1200000	1000000
Holdings-Film	110000	260000	527000	56000h	800000
Intake	16700h	13000h	75000i	35000h	80000i
Circulation	74000	90000	265000	40000	460000

	BBC	TRT	SVT	SWR
Holdings-Video	1000000	100000	200000	1000000
Holdings-Film	600000	70000	-	160000
Intake	110000i	4000i	12000i	30000i
Circulation	350000	15000	45000	80000

The figures for archive input and output add up to, in most cases, several hundred (or more) tape movements per day. This can be viewed as a lot of physical handling which results in the loss of a significant amount of tapes (in some broadcasters this represents

20% of the tapes circulated) and in significant handling and transport costs.

2.4.1 BBC and RTP particular case

Table 2.4 gives information on some aspects on operating an archive in two important European Broadcasters (BBC and RTP).

Table 2.4: Example of 2 Broadcaster Archives operation aspects

	BBC	RTP
Nr items	1.5 Million	700 Thousands
Nr hours	600 000	450 000
Nr inquiries per day	300 to 400	28
Nr tapes or minutes returned on a request	2 to 3 tapes	15min
Usual time required to satisfy a request	90min	60min
Annotation time per hour of video	10min to 10h	1h to 8h
Nr tapes handled in the archive per day	Several hundred	1000
Characterization of the request	50% of the requests fall in the last 1.5 years	80% of the requests fall in the last 5 years
Nr new items intake to archive per year	110 000	15 000

A study carried out by BBC [BBC Archive Steering Group 1998] concerning its own archive showed that, in a one year period:

- i. over 25% of the programme holdings of each decade were loaned;
- ii. material from the 1990s and 1980s account 84% of the loans;
- iii. untransmitted material is less frequently used (8-15% of total used) despite it represents about 80% of the holdings from the 1980s and even more from the 1990s;
- iv. some genres from the BBC archive are used more heavily than others: news/current affairs and light entertainment are the most heavily used while science, religion and children are the least used categories¹;
- v. departments typically make heaviest use of their own material. However at least 50% are from other genres. The exception is the News Department where 95%

¹Sports and natural history were not included in this analysis

of their use is from news and current affairs material;

- vi. customers are mostly internal, being programme makers the heaviest users (70%).

A similar study was undertaken by RTP [RTP - Equipa de Sistemas Documentais 2002] in order to provide the means to improve the efficiency and management of their documental system. The results showed that:

- i. the number of requests from inside the company is considerable superior from the ones coming from outside (about 70% against 30%);
- ii. internally, the biggest client is the Information Department;
- iii. there is a big amount of requests for VHS quality;
- iv. national programmes are more demanded than foreign. However as the relation is of 3 to 1, the second cannot be neglected;
- v. some genres from the archive are used more heavily than others: general iconography² are the most heavily used. Politics and sports are also quite demanded while science and social issues categories are rarely used;
- vi. the analysis of similar studies carried out in 1985 and 1990 shows that the numbers are similar in what concerns to origin of the request and type of request.

These results are quite important for the analysis of the future needs in a digital archive:

- i. holdings from all the decades are heavily used;
- ii. untransmitted material is hardly used compared to its volume. However, as it is generally not catalogued, it might mean that a much stricter policy on cataloguing is required;
- iii. cataloguing is essential for the most recent and most popular genres;
- iv. most recent holdings should be more rapidly accessible;
- v. fragmentation of archive over different locations and different cataloguing policies might result in different usage. An uniform operational policy to ensure access and availability across all the departments is needed.

²Images without any given context such as buildings, traffic, animals, stressed people, etc

2.5 Moving Digital: Challenges and Opportunities

Although most of the areas in a Broadcaster have been profiting from the introduction of new technologies, the library or archive area has been relatively unaffected by technological changes. While networking is being extended to newsrooms, there is still a long way to interconnect archives to the whole production facility. The main reasons for this situation are 1) technology complexity, 2) associated costs, 3) lack business models and 4) the need for a clear workflow definition.

Production environments of the future will need to be open to a great variety of technical standards and they will embrace both the international broadcast community and the multimedia industry.

In this scenario, the archive will be central to the production process and it will need to be managed in an efficient way. Once programme material and its associated administrative information has been turned into digital data, the archive will be liberated from its currently isolated position within television production. It will then become a central asset storage and management system for the entire production process. Metadata will then have a crucial role on challenge of re-using material for different purposes.

Moving towards tape-less digital video production is expected to improve some aspects of a Broadcaster business [Arman 1999; Serb 1997]:

- i. easy and timely access to assets;
- ii. improve workflow;
- iii. enable collaborative work;
- iv. re-use material available in assets;
- v. re-purpose material for different broadcast mediums (from additional channels generated by digital broadcasting to Internet and Web-TV);
- vi. reduce material selection errors.

This is expected not only to increase operational efficiency and reduce production costs but also to provide a potential for more revenue, to overcome competition from other content creators/owners, to improve quality of programmes and to open new business opportunities.

The largest and oldest Television Broadcasters own and keep in archive a lot of material usually in different formats — different analogue and digital video formats as well as

different film formats. RTP and BBC can be taken as examples to characterise this dimension:

- RTP owns one of the largest audio-visual archives in Portugal with more than 700 000 video and film documents amounting more than 400 000 hours;
- BBC owns more than 1.5 million items amounting more than 600 000 hours.

These numbers, presented as an example, are approximated figures as it is difficult to exactly know how big media assets are. Exact information concerning usage, availability of an item and loss of information is not available but some approximated values are thought to be, as partially summarised in Table 2.4:

- i. 85% of the requests coming from the News Department are for recent material (last 3 months);
- ii. cataloguing can take from 10min/hour (quiz show) to 10hour/hour (news magazine);
- iii. answering a request can take from 90 min to weeks if it is an unusual request or a request coming from outside the company;
- iv. number of requests per day can reach some hundreds;
- v. for each request, several tapes are sent;
- vi. to fulfil a single request, hundreds of tapes are handled.

Managing all this information without a significant degree of automation and sophisticated support tools is almost impossible:

- i. islands inside a Broadcasters organisation are usually isolated implying tape handling from place to place that need to be traced;
- ii. transmission of video material, when possible, requires specific synchronous networks with large bandwidth requirements;
- iii. video, sound, control and metadata use different transmission media of high cost and complexity;
- iv. metadata and video are kept separated and are difficult to handle and keep related to each other;

- v. different video archives co-exist inside the same organisation with increased costs of storage and maintenance;
- vi. metadata produced in different working stages is not re-used.

The scenario previously described is not compatible with the need to re-purpose contents for different distribution services (TV, cable, Internet, etc). Situation will become even more complicated with the introduction of interactive television and high-definition. New architectures based on network support have to be defined to enable team production, re-use of essence, simultaneous production for different broadcasting mediums and then reducing costs of operation.

The large number of initiatives, for the definition of both an architecture for storage networking and the multimedia description mechanisms to be used from the producer until the final user of multimedia content, has not yet converged and makes it still impracticable to achieve a standard configuration in most of the areas of a digital television infrastructure.

2.5.1 Implications of MAMs on Workflow and Impact on Personnel Roles

The introduction of server based architectures for the management of video archives will introduce fundamental changes in the workflow process and staff activity [Serb 1997]:

Media Assets in the Newsroom : In a newsroom, rapid access to all type of media assets (from agency feeds, new material from the field or archive) is a requirement. Having all this information available in a digital, server based system increases flexibility and efficiency by reducing the need for specialist researchers and the time spent locating and previewing material. A new job is however created: the ‘Media Manager’ responsible for selecting and controlling input of all incoming pictures, administering storage capacity on the daily server by periodically transferring footage into the archive.

Media Assets in Programme Production : Currently, programme producing requires the use of material available in a variety of formats such as film, tape, transparencies, computer disk and paper. Usually an important amount of this information is lost once the production unit disperses

as there is no centralized management. The archiving process can therefore be difficult and the ability to re-use or reversioning is lost. The introduction of a MAM within the production process increases efficiency by facilitating access to material. As in the newsroom, this new scenario creates the need for a new position — the technician responsible for selecting and organizing all the material in the asset.

Digital Archive : The introduction of digital technology at the beginning of the production process changes procedures for the storage and retrieval of media assets. The traditional reactive operation of the archive (documentation and storage of material after transmission) should be changed to a pro-active process where information is captured early in the production chain. This process still requires human intervention to describe the material. The role of the researcher will, however, decline as the ability to search and preview material available in servers will not demand for specialist skills. Staff for retrieving film and tapes, although still required as prohibitive costs make it unlikely that entire archives will be digitised, is expected to diminish as the amount of material available on-line increases.

Different applications areas require different functions and parameters for implementing MAMs: a short access time is more highly valued for the compilation of news programmes than for the access to a stored soap opera. The SMPTE Study Group V16.09 [Heitmann 1998; SMPTE 1998] defined a list of functions or parameters that should be considered for some application areas and the rate of importance for each, as summarised in Table 2.5.

2.5.2 Cost per Use

Migrating from the existing archiving systems and practices to more efficient ones raises the question of how to estimate additional expenses and benefits.

Value of archive content is derived mainly from the level of re-use. Having material available or, at least, searchable online is an important aspect for making archives profitable as some external users are already selecting their sources using these factors as a criteria [Whittaker 2001]. It is expected [Wright and Williams 2001] that digitisation and online storage can double the usage of the asset, although this process is estimated [Wright 2002] to be 50% more expensive than just transferring tapes from older to new formats.

Table 2.5: Requirements for MAM functions in different applications

Functions	Applications			
	Broadcast Programmes	Broadcast News	Film Stock for Broadcast	Historical Film Stock
Online catalogue	+	+	+	+
Browsing	+	+	-	+/-
Short access time	+	++	-	+/-
Simultaneous access	+/-	++	-	+/-
Networking	+	++	-	+/-
Compression				
Size of files	↑	↑	↑	↑
Play out via disk server	++	++	-	+/-
Frequency of access	+	++	+/-	-

‘++’: *Very Important* ‘+’: *Important*
 ‘+/-’: *Less Important* ‘-’: *Not Important*
 ↑ *Big* ↑ *Medium*

PRESTO defined the concept of ‘cost per use’ which is related to the number of times that an asset is used over the lifecycle. Although not every use has equal benefit, it is likely that more content issued from the archive means more benefit to the broadcaster and to the wider public service. Therefore a simple way to combine transfer cost to a new support, life cycle cost and the significance of new service opportunities, is to translate those new opportunities into a predicted rate of item usage.

As it was referred in Section 2.4, 20 to 30% of the archive content is issued to users each year. However as just 25% of that is requested in broadcast quality and it is estimated that 75% of that material is not actually used in programme making, a given archive item has a probability of $\frac{1}{16}$ of ending up actually being shown in a new programme every time it is issued. Estimating that a tape has 20 years life expectance, means that a given item has approximately $\frac{1}{4}$ probability of future use. This probability can be expected to raise to $\frac{1}{2}$ if the archives migrate to a more efficient process.

Having to provide migration of items due to preservation requirements, the concept of ‘cost per use’ shall be considered on the definition of the strategy of like-for-like copying or digitisation and mass storage.

2.5.3 Selection Criteria

Besides technical complex issues imposed by the transition to digital, digitising archives is expensive and time consuming. Possible incoming sources to the archive are

- i. material from the legacy archive;
- ii. incoming footage from production or acquisition in the field;
- iii. feeds from news agencies;
- iv. live signals;
- v. material acquired to other broadcasters or independent producers.

A criteria on transfer priority has then to be defined through a consistent policy that ensures that no material of potential value is discarded due to incorrect selection procedures or degradation.

Archives have already to develop selection procedures on the everyday income footage. In order to assure that some uniform criteria is observed, FIAT provides a recommendation for the keeping of material [FIAT - Programming & Production Commission 1996] that can be summarised as follows:

- i. material of historic interest in all fields;
- ii. material as a record of a place, an object or a natural phenomenon;
- iii. interview material of historic importance;
- iv. interview material indicative of opinions or attitudes of the time;
- v. fictional and entertainment material of artistic interest;
- vi. fictional and entertainment material illustrative of social history;
- vii. any material, including commercial and presentational, illustrative of the development of televisual practices and techniques.

This methodology shall be applied both to transmitted and untransmitted material. Transmitted material shall always be kept while for untransmitted material the first four points are of more relevant importance.

Even though, several selection and archiving policies are observed in different broadcasters: final clips and selection of rushes versus final clips only or several levels for selection before archiving.

Based on the FIAT selection process and on the known operation aspects of RTP and BBC archives, the following priority criteria for populating the digital archive is suggested:

- i. all the programmes daily broadcasted;
- ii. material on risk of deterioration or in old formats;
- iii. most frequently used genres as news, sports and politics;
- iv. material of irreplaceable images such as a city before a catastrophe or a natural phenomena;
- v. material omitted from transmission for reasons of censorship;
- vi. images with reuse potential as that of personalities or happenings of contemporary importance
- vii. most recent material if not yet in digital format.

2.6 Concluding remarks

The characterisation of the broadcasting archives current situation is quite important on the definition of requirements for the development of new solutions based on digital technologies.

Architectures of future systems will be influenced by a deep knowledge of archives operation aspects. The overview presented in this chapter is intended to provide generic information, problems and principles that are common to most television archives. The particular and detailed information of two important archives in Europe, as RTP and BBC, was thought also to be relevant to this thesis: one was used as the testbed for the prototype developed and the second enabled the validation of some of the principles used.

The first conclusion that can be drawn from the work carried out to complete this chapter is that it is quite difficult to get accurate information about different aspects. The numbers presented resulted from interactive contacts with various Broadcasters' departments and of continuously updating information. They have however turned out to be quite important on the definition of the architecture presented in Chapter 5.

Another important conclusion is that the development of a MAM is quite complex as the amount of information is tremendous and constantly increasing and it is spread across the organisations in a number of different formats that face deterioration problems or are obsolete.

The third conclusion is that tape handling and transport (a risk both because a large number of tapes is lost in this process and because they are exposed to environmental conditions that reduce their lifetime expectancy) can be reduced if efficient search and access mechanisms are provided to the final user.

The interest of users about items in archive is not uniform but depends mainly on the genre and age of the material. This conclusion can be used on the dimensioning of hardware and on the definition of material selection policies.

Although the archives are considered, by the owners, to be heavily used, an increase of usage has not been noticeable in recent years. This can be seen as a contradictory aspect in the current scenario of constantly deployment of new audio-visual systems and can reveal that archives are still not correctly explored.

Chapter 3

Video Description Schemes in Broadcasting

The large amount of information in a Broadcast Archive makes it quite difficult to efficiently locate a resource for re-use or re-purposing. In response to the needs of industries and users to solve this problem, different organisations have recently initiated active work on the definition of interoperable frameworks and representation for metadata. This chapter presents the recommendations given by user and standardisation organisations and addresses the main metadata initiatives that are relevant to broadcasting.

3.1 Introduction

The effective use of an audio-visual archive is not possible unless some extra information is introduced to help describing the multimedia material (not only audio and video descriptors but also business and management information). This information, usually referred as ‘Metadata’, main benefits are [EBU/SMPTE 1998; Drewery and Riley 1999]:

- i. effective re-use of archived material;
- ii. efficient re-purposing;
- iii. faster and flexible archive searching;
- iv. video material interchange among different producers and organisations;
- v. property rights management;

- vi. improvement in file organisation and management (including backup, content verification, charging, etc);
- vii. development of new business and markets to make profitable costly content assets.

As defined in Section 1.4, *Metadata* is data about data or a summary of the form and content of a resource. Structured metadata is divided into elements, each of which describes a particular aspect of the information resource. Consistency is important for effective information management and retrieval, so clearly defined standards must be set and widely applied.

During the last few years, a number of organisations and individual institutions have been working towards the definition of an uniform video description schema as well as description languages and descriptors.

However, metadata is usually not only content but also domain-dependent [Aberer et al. 1999] what means that different sub-sets and variations have been designed for a specific audiovisual application or use (radio and television broadcasting, audio and video post-production, multimedia libraries, news agencies, Web TV, etc), or focusing on specific aspects of the production, archiving or distribution process. An obstacle for the common use of generic standardised metadata schemas is also that a model often reflects the business model of organisations. For these reasons the level of implementation of standardisation is limited.

As the workflow of both essence and metadata are evolving from the traditional linear content chain to an asset centric chain, interoperability among metadata schemes or descriptors is even more fundamental. Figure 3.1 outlines the stages involved in Content creation that are expected, as defined by EBU [EBU 2001b], to contribute Metadata for workflow enhancement. Currently, descriptive metadata created during earlier stages of the production process is either lost or has to be manually re-entered in the archive. The asset centric model should collect and keep metadata during the full life-cycle of Essence, from pre-production to archiving.

EBU recommends [EBU 2001a] that a MAM is required to support the following metadata categories:

- i. Cataloguing
- ii. Descriptive

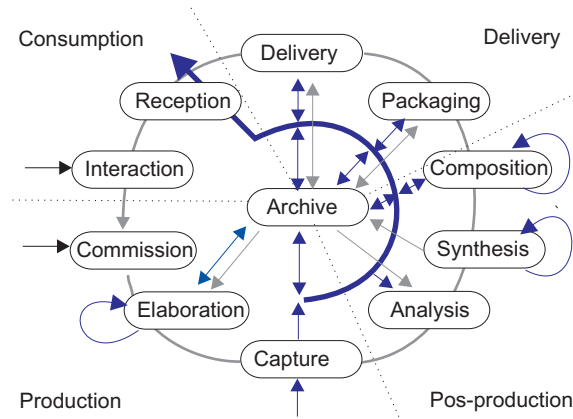


Figure 3.1: Workflow in Content Creation

iii. Indexing

iv. Technical data about Essence and physical carriers

Some of the most important work that is being carried out by different organisations as a response to the needs of industry and users on metadata for networked audiovisual systems include, but are not limited to, the ones presented in the next sections. These standards are essential so that a unique representation with unique meaning is used and machines can be used to perform automatic tasks to search and operate in media. This automation is the only way to handle and conveniently exploit the huge volumes of essence currently in storage (many hundreds of thousands of hours).

The approaches presented in this chapter share similar objectives and have developed some correspondence between their frameworks. However there is also important divergence that will require nontrivial harmonisation and synchronisation [Viana 2006].

3.2 Currently used Metadata

Currently, most television archives use a common list of items [Grego et al. 2001] as presented in Table 3.1.

Although these descriptors can be regarded as almost standard, there are still a lot of problems concerning the interoperability of systems and the usability of the archive as, for example, locating a specific image in a video stream is still very difficult and time consuming.

Table 3.1: Metadata commonly used in Broadcasting

Class	Descriptors
<i>Descriptive</i>	Title
	Subtitle
	Episode Number
	Technical Sheet
	Duration
<i>Technical</i>	Recording Format
	Colour
	Ratio
	Sampling
	Sound
	Quality of Picture and Audio
<i>Catalogue</i>	Usage of Tape
	Tape number
	Archiving Number
<i>Broadcasting</i>	Production Number
	Broadcast Date
	Broadcast Channel

The extract of a film catalogue from [AMIA's Cataloging and Documentation Committee 2001] (Table 3.2) gives an example of the current practice. Beside using, incorrectly, the **Description** field for different purposes, this field is also used to list timecodes. This approach makes it quite difficult to easily access a required image.

This situation led to an attempt of standardising metadata as a process of associating extra information to essence and making items really available. Numerous organisations and projects are working in similar areas. The next sections briefly refer to some of the most important initiatives.

3.3 FIAT/IFTA Minimum Data List

The International Federation of Television Archives (FIAT/IFTA) defines a set of descriptors called the 'Minimum Data List' (MDL) [FIAT/IFTA Documentation Commission 1992] whose purpose is 1) to serve as a standard for newly established television archives and 2) to guarantee that a certain minimum amount of information will be found in a television archive which can be used in the exchange of information between different owners. This list specifies a core set of descriptors grouped into different classes as defined in

Table 3.2: Extract from AMIA Compendium of Moving Image Cataloging Practice

1	Title	A Woman of Evil
2	Year	1950's
3	File Number	AFP-42B0, AFP-42BP, AFP-42BQ
4	Size	16mm
5	Color	B&W
6	Type	Sound Feature
7	Description	Starring Jeanne Moreau (Queen Margot),
8		(...) Adapted by Abel Gance from
9		Alexandre Dumas' novel
10		"Marguerite of Navarre". Directed by Jean Dreville.
11		"French costume drama, set in 1572, (...)
12		AFP-42B0:
13		0:04:30 Two French noblemen swordfight
14		0:06:12 Man on horse reads public announcement
15		0:15:00 Ballroom scene: staid, formal dancing

Table 3.3.

The MDL does not exist in a machine-readable form. An appropriate conversion is therefore necessary.

The problems identified in the last section are similar in this approach as no mechanisms for breaking the content in its components are provided.

3.4 Dublin Core Metadata Initiative

The Dublin Core Metadata Initiative (DCMI) is an open forum engaged on the development of interoperable metadata standards that support a wide range of networked resources. Although its former intention was the representation of bibliographical information on the web, it has evolved to a standard that aims at allowing the creation of simple descriptive records for any information resources (e.g. electronic documents, JPEG images, video clips).

The DCMI defines a set of 15 main descriptors — the Dublin Core Metadata Element Set (DCMES) — and was initially released as a standard from IETF [Weibel et al. 1998]. Lately, DCMES has also been formally endorsed as ISO15836-2003 [ISO 2003] and NISO Z39.85-2001 [NISO 2001] standards. Those descriptors are organized in three groups which indicate the class or scope of information stored in them: 1) elements related mainly to

Table 3.3: FIAT/IFTA Minimum Data List

Class	Descriptors
<i>Identification</i>	Title Given Title Subtitle Other Titles Date of Transmission Data of Shooting Producer Production Number Archive Number
<i>Technical Data</i>	Content Keywords Place of Shooting Running Time Language Medium Format and Standard Sound Colour or B&W
<i>Rights Management</i>	Origin Contracts Copyrights Producer Other Names

the Content of the resource, 2) elements related mainly to the resource when viewed as Intellectual Property, and 3) elements related mainly to the Instantiation of the resource related to different aspects. The semantics of each of these elements have been established through consensus by an international, cross-disciplinary group of professionals. Each of these elements (Table 3.4) is optional, may be repeated and may have different formats — the **Identifier** can, for example, be a uniform resource locator (URL) for a web page, an ISBN for a book or even a UMID for a video.

These reduced list of terms can be extended or further refined as exemplified in Table 3.5 for the **Date** and **Title** core elements [DCMI 2003].

The Dublin Core Metadata Initiative provides access to schemas defining DCMI term declarations using RDF (Resource Description Framework) [W3C 2004c] and XMLs (XML

Table 3.4: Dublin Core Metadata Element Set

Class	Elements	Description
<i>Content</i>	Title	A name given to the resource
	Subject	The topic of the content of the resource
	Coverage	The extent or scope of the content of the resource
	Description	An account of the content of the resource
	Type	The nature or genre of the content of the resource
	Relation	A reference to a related resource
	Source	A reference to a resource from which the present resource is derived
<i>Intellectual Property</i>	Contributor	An entity responsible for making contributions to the content of the resource
	Creator	An entity primarily responsible for making the content of the resource
	Publisher	An entity responsible for making the resource available
	Rights	Information about rights held in and over the resource
<i>Instantiation</i>	Date	A date associated with an event in the life cycle of the resource
	Format	The physical or digital manifestation of the resource
	Identifier	An unambiguous reference to the resource within a given context
	Language	A language of the intellectual content of the resource

Schema) [W3C 2004d].

Dublin Core is not a full set of metadata capable of fulfilling most of the aspects of a broadcast archive [Wright 2003] not only because there are legacy systems which use approaches previous than Dublin Core but mainly because there are various types of broadcasting metadata that are not within the scope of Dublin Core as 1) technical metadata (e.g. timecode); 2) preservation transfer metadata (e.g. number of dropouts in this recording); 3) documentary metadata (e.g. transcript, running order); 4) transactional metadata (e.g. loan period; charges for overdue material).

However, due to its active work, this initiative has been considered of interest within other broadcast oriented projects on metadata.

Table 3.5: Example of DC element refinement

Element	Refinement	Description
Date	Created	Date of creation of the resource
	Valid	Date (often a range) of validity of a resource
	Available	Date (often a range) that the resource will become or did become available
	Issued	Date of formal issuance (e.g. publication) of the resource
	Modified	Date on which the resource was changed
Title	Alternative	Any form of the title used as a substitute or alternative to the formal title of the resource

3.5 EBU Metadata standards

EBU has been developing some work on the definition of schemes that enable the exchange of information between different partners. A standard established in 1995 [EBU 1995] enabled the categorisation of programmes and served as the base for the later P_Meta description scheme presented below.

3.5.1 EBU System of Classification of Radio and Television Programmes

The EBU programme classification scheme — EBU System of Classification Of Radio and Television programmes: ESCORT 2.4 [EBU 1995] — uses a number of elementary dimensions, grouped into a set of classes, concerned not only with the description of the form and content of the programme but also with the way in which the programme was produced/acquired, how it was scheduled and transmitted, how it was received by the audience and the costs involved.

This scheme can be applied to the smallest time unit of a programme (e.g. a minute), to programme items, complete programmes or even to a station or channel and is developed in a hierarchical organisation as the extract presented in Table 3.6.

The aim of this scheme is to identify common reference data (*Attributes*) and its definition to enable public service broadcasters to have reliable and internationally comparable data regarding their activities. This model doesn't provide a coding format for the meta-data but just a uniform set of codes that enable the classification of a programme. Some examples of its use are presented in Table 3.7

Table 3.6: Extract of the ESCORT 2.4 Classification Scheme

Class	Sub-class
<i>A. Programme Conceptual Data</i>	1. Intention 1.1 Entertainment 1.1.1 Pure entertainment 1.1.2 Informative entertainment 1.2 Information ... 2. Format 2.1 Non-Fiction 2.2 Drama 2.2.1 Performed drama 2.2.2 Drama with puppets 2.2.3 Animated drama 2.3 Entertainment 2.4 Music/Ballet/Dance 3. Content ... 4. Target group ... 5. Origination ... 6. Language ... 7. Participation
<i>B. Administrative Data</i>	
<i>C. Programme Acquisition Data</i>	
<i>D. Scheduling Data</i>	
<i>E. Transmission Data</i>	
<i>F. Listening/Viewing Data</i>	
<i>G. Financial Data</i>	

3.5.2 EBU P_Meta

The EBU P_Meta Scheme [EBU 2007; Hopper 2002] defines a set of attributes that have been identified to support the exchange of programme content between EBU members as 1) content creators, 2) distributors and 3) archives. It supports the exchange of metadata — with or without content — based on agreed definitions of *Attributes*, *Attribute Type* values, *Sets of Attributes*, *Sets of Sets*, *Unique Identifiers* and *Protocols* in a scenario of Business-to-Business (B2B) between three identified actors (the *Producer*, the *Distributor* and the *Archive*) as shown in Figure 3.2. A B2C scenario is also defined.

Four main objectives, for the B2B exchange scenario, have been identified:

Table 3.7: Examples of ESCORT 2.4 Classification

Programme Title	A1 Intention	A2 Format	A3 Content	A4 Target	A5 Origin
My Fair Lady	111	245	343	41	52
Eurovision Song Contest	111	243	344	41	51
Soccer match	112	213	314	41	54

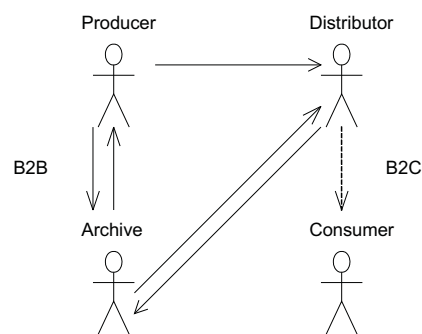


Figure 3.2: P_Meta Business process model

- i. to allow the identification and recognition of material;
- ii. to provide an editorial description of material;
- iii. to establish the right to use the material;
- iv. to provide a minimum core of technical details.

Content that can be the object of exchange belongs to one of the classes:

- i. **Programme**: an audio-visual work that has been defined and created by a commissioning decision.
- ii. **Programme Group**: a collection of **Programmes**.
- iii. **Programme Item**: a constituent part of a **Programme**.
- iv. **Item Group**: a collection of items grouped as part of a programme, or otherwise editorially related.

- v. **Media Object**: a single component of a programme or item, of a single media type. It is continuous in time.
- vi. **Brand**: a collection of assets with a recognisable collective identity.

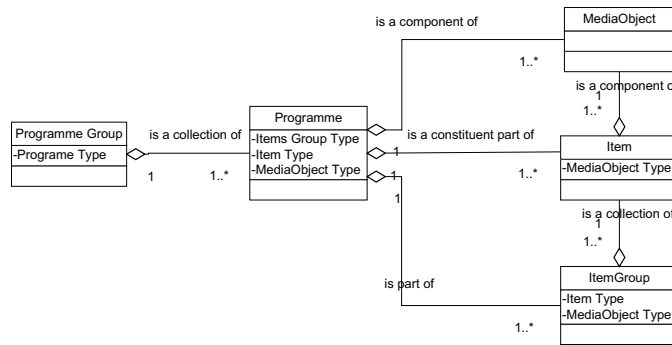


Figure 3.3: P_META main entities

The diagram in Figure 3.3 represents the relationships between the main entities defined.

The simplest element — the *Attribute* — has an identifier, a name, a description, a type, any known aliases and some examples associated, in a similar way as the SMPTE MDD presented in Section 3.7.1. Besides this flat list of descriptors, P_Meta defines the concept of a *Set* — a collection of commonly-used *Attributes* required to support business transactions and that identifies a given context. Some defined *Sets* include areas as Identification and Recognition, Description, Rights, Technical and Transaction actions.

Together with the list of *Attributes* and *Sets*, P_Meta provides the notation to be used on the representation and definition of these concepts. Table 3.8 gives an example of the syntax and notation used to express the `PROGRAMME_DESCRIPTION` *Set*. Square brackets delimit the *Set* description; vertical bars are used to represent alternative *Attributes* or *Sets* and brace brackets are delimiters for repeating groups. The cardinal expresses the number of occurrences of any information element in a Set — the award name attribute (as a repeating group) in s39 is used to communicate any awards won by the programme in question; in the same repeating group the festival name attribute is used to communicate the ceremony associated to the award. A cardinality of `1 | .. | 1` is used to define mandatory elements as the `SUBTITLE_FLAG` in the example.

Table 3.8: P_Meta Set S39:PROGRAMME_DESCRIPTION

1	[
2	0 LANGUAGE_CODE LANGUAGE_NAME 1:
3	S46(SET_DATA_VALIDITY_TIMESTAMP):
4	EOV_DURATION:
5	PROGRAMME_SYNOPSIS_DESCRIPTION:
6	PROGRAMME_SCRIPT_DESCRIPTION:
7	COLOUR_CODE:
8	1 SUBTITLE_FLAG 1:
9	S18(LANGUAGE_HISTORY):
10	S10(LOCATION):
11	S17(KEYWORD):
12	0{
13	WARD_NAME:
14	FESTIVAL_NAME
15	}n:
16	0{
17	S73(REVIEW_DETAILS):
18	}n:
19	0{
20	1 SIGN_LANGUAGE_CODE SIGN_LANGUAGE_NAME 1:
21	SIGN_LANGUAGE_PRIMARY_LANGUAGE_INDICATOR:
22	SIGN_LANGUAGE_TRANSLATION_INDICATOR
23	}n
24	]

A XML representation is also provided as illustrated in Table 3.9 for the same `PROGRAMME-DESCRIPTION` concept.

P_Meta makes use of the former ESCORT 2.4 classification scheme mapping some of its `Attributes` to its scheme.

Exchange of metadata associated to essence can be done in several ways: isolated, embedded into streams or encapsulated within files, using for that external standards for data coding and transport as XML, KLV, SDI, MPEG2, MXF, etc.

An important remark is that P_META Scheme is not directly associated with schemes designed to model storage. *Attributes* and *Sets* can be assembled in any arrangement that is useful for a business transaction and are not defined through mutual relationships. However, due to the harmonisation need between different schemes, some work is being done for the development of generalised meta-classes that represent P_Meta [Boch 2002].

Table 3.9: P_Meta PROGRAMME_DESCRIPTION in XML

1	<pmeta:ProgrammeDescription>
2	<pmeta:DataDefaultLanguage> ... </pmeta:DataDefaultLanguage> [0..1]
3	<pmeta:Duration> ... </pmeta:Duration> [0..1]
4	<pmeta:ProgrammeSynopsis> ... </pmeta:ProgrammeSynopsis> [0..1]
5	<pmeta:ProgrammeScript> ... </pmeta:ProgrammeScript> [0..1]
6	<pmeta:ColourCode> ... </pmeta:ColourCode> [0..1]
7	<pmeta:SubtitleFlag> ... </pmeta:SubtitleFlag> [1]
8	<pmeta:LanguageHistory> ... </pmeta:LanguageHistory> [0..1]
9	<pmeta:Location> ... </pmeta:Location> [0..1]
10	<pmeta:Keywords> ... </pmeta:Keywords> [0..1]
11	<pmeta:Award> ... </pmeta:Award> [0..*]
12	<pmeta:ReviewDetails> ... </pmeta:ReviewDetails> [0..*]
13	<pmeta:SignLanguageDetails> ... </pmeta:SignLanguageDetails> [0..*]
14	</pmeta:ProgrammeDescription>

3.6 ETSI Metadata standards

3.6.1 DVB-Service Information

The European Telecommunications Standards Institute (ETSI) provides some mechanisms, to be used in the scenario of Digital Video Broadcast (DVB), that enable simple content description. The *Service Information* (SI) data [ETSI 1998], which forms a part of DVB bitstreams, can be used to supply information that can assist on the selection of events within the bitstream.

Information on a programme is made available through a set of *Selection Information Table* (SIT) that provide classification of the content into a category, the name of the event and even a short description of the event (EIT - *Event Information Table*), or the identification of the service provider (SDT - *Service Description Table*).

The same theme categories are used in the Electronic Programme Guide (EPG) [ETSI 2003] defined by ETSI and follow a two level hierarchy that differs from the EBU/Escort system of classification.

3.6.2 TV-Anytime

Another solution coming originally from an industrial forum with a large number of companies and individuals participating and published by ETSI is the standard known as

Table 3.10: Extract of the DVB event classification table (EIT)

Class	Sub-class
0x1 Movie/Drama	0x0 movie/drama (general) 0x1 detective/thriller 0x2 adventure/western/war 0x3 science fiction/fantasy/horror
...	
0x5 Children's/Youth Programmes	0x0 children's/youth programmes (general) 0x1 pre-school children's programmes 0x2 entertainment programmes for 6 to 14 0x3 entertainment programmes for 10 to 16 0x4 informational/educational/school programmes
...	

TV-Anytime (TVA) [ETSI 2006b; Evain 2000]. This standard defines not only a meta-data scheme able to describe content to be delivered to a set of different terminals (mobile phones, PDAs, personal video recorders, etc), but also the architecture and communication aspects to be considered when implementing a TV-Anytime compliant system.

This proposal covers aspects directly related to the consumer and is expected to enhance the DVB-SI approach and to enable the creation of personalised programme guides that help on the tracking of programmes that correspond to the consumer preferences.

The Forum is organized in various groups dealing with the following aspects:

1. Business Models
2. System
3. Transport Interfaces
4. Content Referencing
5. Rights Management and Protection.

TV-Anytime has defined a unique document structure (Figure 3.4) to aggregate programme descriptions, user descriptions or classification schemes (e.g. Content/genre, Action-Type, ContentCommercial, HowRelated, TVARole).

A TVA system is articulated around the Content Referencing Identifier (CRID) [ETSI 2006c]. A CRID relates to a specific content/programme instance, or to other CRIDs

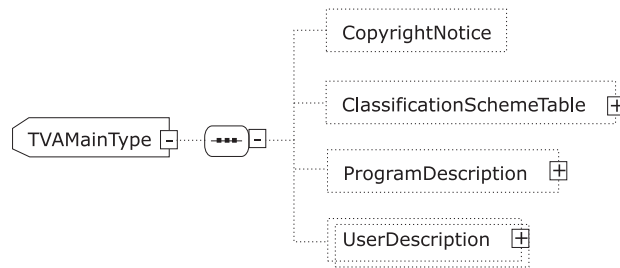


Figure 3.4: TV-Anytime main schema

themselves referring to other different instances. The CRID is also the link between a content instance and its associated metadata. To enable some flexibility, TVA uses XML as the representation language and allows the refinement of the descriptions by adding extra information. Figure 3.5 presents the main structure used for describing a Programme.

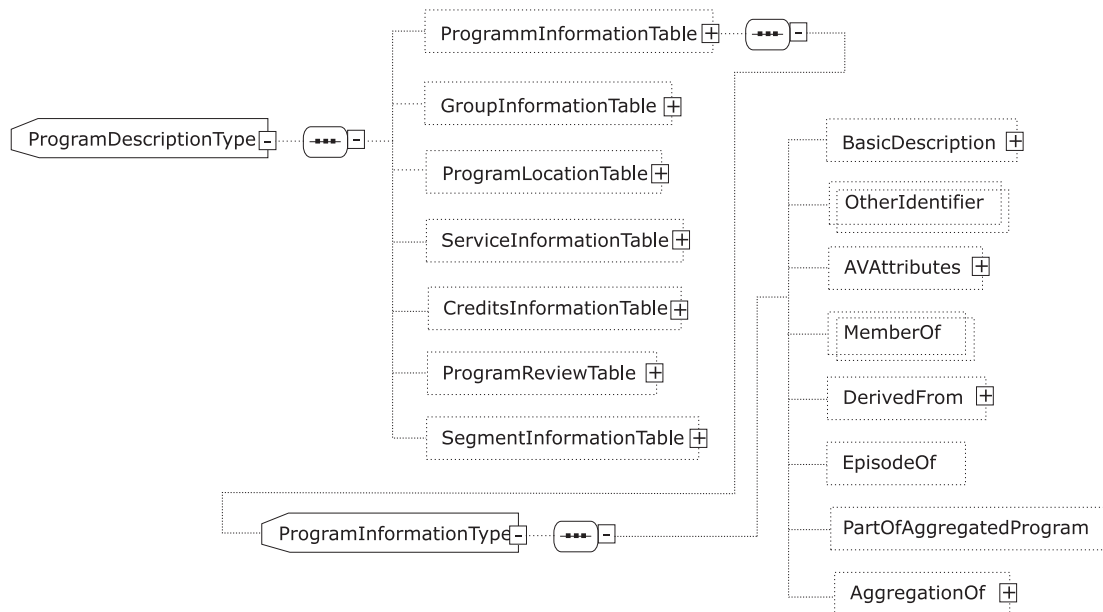


Figure 3.5: TV-Anytime Programme Description Schema

The structure defined enables the description of the following content concepts [Evain and Murret-Labarthe 2003]:

- i. Simple programmes using **ProgramInformation** descriptions;

- ii. Programme versions (e.g. different edits) differentiated using `BasicDescription`;
- iii. Commercials (programme trailers), e.g. using the `PromotionalInformation`;
- iv. Groups of related programmes with `ProgramInformation` (using `MemberOf` and `EpisodeOf`) and `GroupInformation`;
- v. A programme that is a concatenation/group of sequences of other programmes (`ProgramInformation.PartOfAggregatedProgram`), identified as an aggregated programme (`ProgramInformation.AggregationOf`);
- vi. The publication of a programme that may have publication-dependent attributes (e.g. a film tribute to a recently deceased actor which would have a different description) using a `ScheduleEvents` or `BroadcastEvents` or `OnDemand-Programs.InstanceDescription`;

3.7 SMPTE Metadata standards

The number of SMPTE standards for the definition and transport of metadata in a television environment is quite complex. Different phases as well as different areas are involved in this process as shown in Figure 3.6.

Some recent and important standards include the SMPTE Metadata Dictionary (MDD) and the MXF DMS-1 scheme.

3.7.1 Metadata Dictionary

SMPTE defines a set of descriptors — the ‘Metadata Dictionary’ [SMPTE 2001a,c] — covering different aspects of the production chain. The Dictionary consists of *Structure* [SMPTE 2001a] and *Content* [SMPTE 2001c] and its metadata elements cover aspects that range from technical information on video/audio encoding characteristics, to information on how the essence was processed/manipulated, who was the supplier and what are the rights, and interpretive information as a narrative summary or a title.

Within this scheme, metadata elements are organized into a hierarchical structure of nodes and leaves as defined in [SMPTE 2001b]. The top level forms one of the 15 defined classes (nodes) that are further divided in sub-classes (sub-nodes) which enable increasingly fine node definition. Entries within a subclass are the data elements or leaves.

Each of the defined classes represents a collection of metadata elements with common

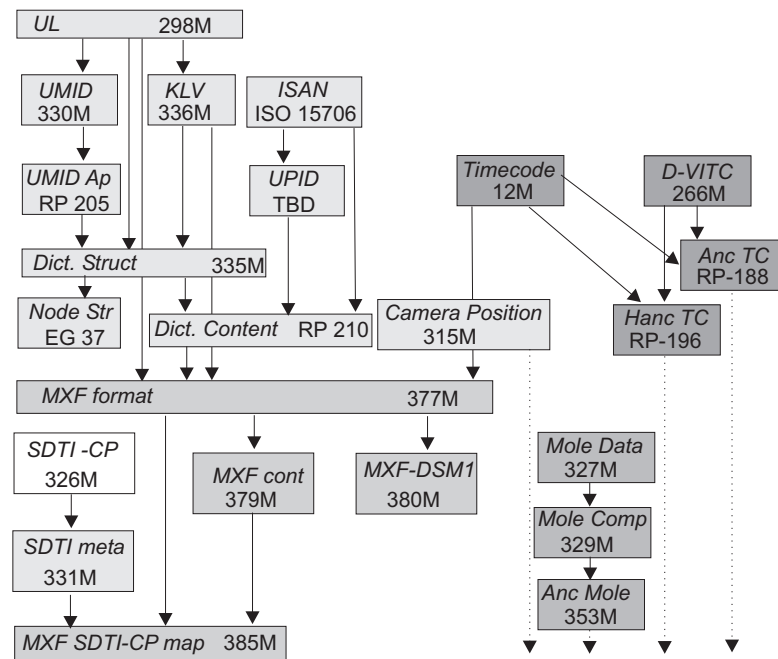


Figure 3.6: SMPTE metadata standards

characteristics as described in Table 3.11. Figure 3.7 gives a partial view of the SMPTE dictionary tree structure showing examples of existing nodes and leaves.

Individual items (or metadata elements) are referenced through a two-part 16-byte universal label, as defined in SMPTE 298M [ANSI/SMPTE 1997b], that is numerical (language independent) and unique. The first eight bytes of this key identify the dictionary and version number where the metadata element first appeared while the second eight bytes identify the particular metadata element. The dictionary also contains information on the required format of metadata values and the allowable range as illustrated in Table 3.12.

One of the important entries of *Class 1* is the ‘Unique Material Identifier’ (UMID) defined in SMPTE 330M [SMPTE 2004b] which provides the mean for uniquely identifying material, be it picture, audio or data, through a 32 byte (basic UMID) or 64 byte (extended UMID) word¹. Besides identification, the UMID also provides mechanisms to link different

¹Some other standards for content identification exist. Examples in the area of audiovisual are the ISO-International Standard Audiovisual Number (ISAN) [ISO/TC46/SC9 2002], the Content ID Forum-Content Identification (CID) [Content ID Forum 2003] and TV-Anytime Content Reference Identifier (CRID) [ETSI 2006c]

Table 3.11: SMPTE Metadata Classes

Class		Description
Nr	Name	
1	Identification and location	All forms of metadata used to uniquely identify an item
2	Administration	IPR, ownership, user access, encryption, audience
3	Interpretive	Human-generated description as names, artists, classification, summary used mainly for cataloging and searching
4	Parametric	Signal coding parameters like aspect ratio, colorimetry, compression or tape format
5	Process	Describes how essence was processed or changed after its origination (editing information, versions, etc)
6	Relational	Describes relationships among objects
7	Spatio-temporal	Places and time
8	Publicly registered	Individual elements defined by a registered organisation and publicly available
9	Organisation registered	Individual elements defined by an organisation for private use
10	Experimental	Transient metadata to be used within a laboratory environment

versions of the same material (e.g. a high resolution and a browse copy or a B&W version) or to link material with associated metadata through the use of a *Material* and *Instance* numbers. This concept allows the easy tracking of related material and also the easy identification of the original material as it always keeps the *Instance Number 0*. Extra information, as time of creation and identification of producer, can be introduced by the use of the extended UMID version.

SMPTE provides mechanisms for representing the dictionary and encoding metadata to be transported through different interfaces: the Key-Length-Value protocol (KLV) [SMPTE 2007] defines a triplet as a data interchange protocol for data items irrespective of the method of implementation or transport. The *Key* identifies the data, the *Length* specifies the length of the data and the *Value* is the data itself. The use of this binary coding enables an easy interconnection with audio and video essence data. Alternatively, XML encoding can be used as KLV can be transparently converted into XML and vice versa.

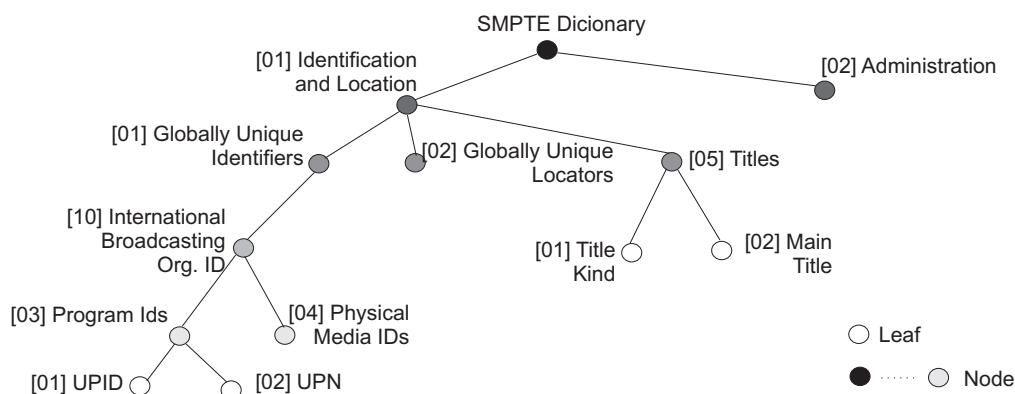


Figure 3.7: SMPTE Metadata Tree Structure

Table 3.12: SMPTE dictionary

SMPTE Label	Name	Definition	Type	Lenght
01.05.00.00.00.00.00.00	Titles	Titling metadata relating to productions		
01.05.01.00.00.00.00.00	Title kind	Kind of title, i.e., project, group of programmes, group of series, series, item, programme, working, original, item, episode, element, scene, shot etc	ISO/IEC 646:1991	127 bytes max
01.05.02.00.00.00.00.00	Main title	The main title	ISO/IEC 646:1991	127 bytes max
01.01.10.03.01.00.00.00	UPID	A Unique Program Identifier (ATSC A/57) for a programme as a Work	As per ATSC standard	

3.7.2 DMS-1

The work under development in SMPTE towards the definition of a standard wrapper for the exchange of both essence and metadata — The Material Exchange Format (MXF) [SMPTE 2004c] — led to the definition of Descriptive Metadata (DM) Frameworks collectively called the *MXF Descriptive Metadata Scheme 1* (DMS-1) to be used as part of the MXF Header Metadata.

A DM Framework is a grouping of related Descriptive Metadata attributes and sets (groups of attributes) that describe content and give contextual meaning: a given metadata set can be used in more than one Framework and its meaning is clearly identified by the context of use.

Three Frameworks are defined: 1) Production, 2) Scene Framework and 3) Clip. The first provides identification and ownership details of the audiovisual content (that can be an individual programme, a set of programmes or a programme item), while the second describes actions and events within individual scenes (editorial concept characterised by narrative coherence) of the audio-visual content and the last provides capture and creation information about the individual audio-visual clips (a continuous essence element).

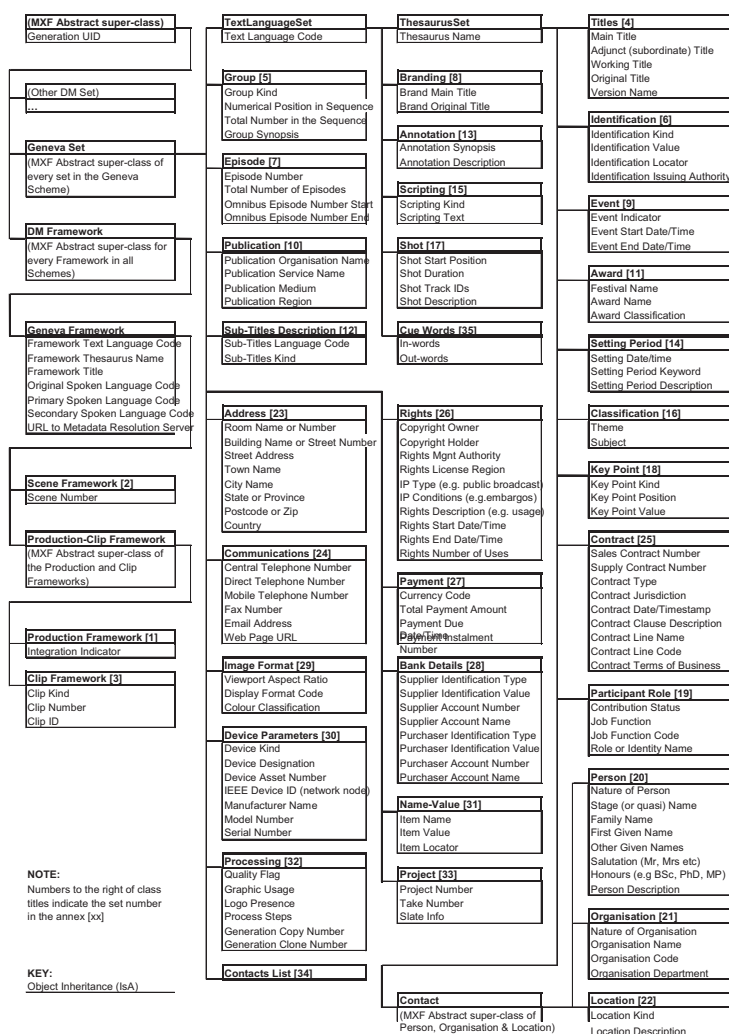


Figure 3.8: DMS-1 Class Structure

The standard follows an Object Oriented (OO) approach defining class models (Figure 3.8) that represent the inheritance and aggregation relations between Frameworks and

Sets of attributes enabling then a more structured approach of essence description when compared to the MDD. The harmonisation between the two initiatives is provided by the inclusion of a reference to the MDD for each metadata element.

3.8 ISO MPEG-7

MPEG-7 (Multimedia Content Description Interface) [ISO/IEC 2002b; Manjunath et al. 2002; Martinez et al. 2002; Martinez 2002] provides a standardised content description for various types of audio/visual material and is not intended to be used in a particular area but to be applied to such distinct applications as surveillance, home entertainment, broadcast channel selection, educational applications, etc.

The standard defines:

1. descriptive elements — the *Descriptors* (D) — that define the syntax and the semantics of each metadata element and can range from very low-level signal features like colours, shapes and sound characteristics, to high-level structural information about content collections as the owner;
2. *Description Schemes* (DS), that specify the structure and semantics of the relationships between components (Ds or DSs);
3. a *Description Definition Language* (DDL) that defines the syntactic rules to express and combine Ds and DSs;
4. a set of mechanisms to support efficient storage and transmission like coding schemes and synchronization between descriptions and content.

MPEG-7 data can be represented either in textual format (TeM — Textual format for MPEG-7) or in binary format (BiM — Binary format for MPEG-7) or a mixture of the two formats, depending on application usage. The TeM, defined by the DDL, is based on the XML schema language, with extensions to support extra requirements like array and matrix data types, and is suitable for editing, searching and filtering. The BiM is a binary form suitable for storage, transmission, and streaming delivery.

In contrast to other solutions presented in this section, MPEG-7 defines very granular abstraction levels which are related to the way the descriptors can be extracted: low-level information as shape, texture, colour or trajectory are expected to be extracted automatically while high level descriptors as content creation information need human

interaction. This granularity enables the offering of classical archive-oriented descriptions (title, broadcasting dates, content genre, storage formats, etc) as well as object-oriented-like descriptions that enable the decomposition of a video segment into its component objects. This is provided by a hierarchy of descriptions that range from *basic elements* to *content organisation*.

Besides MPEG-7, the MPEG group is also working on the development of the MPEG-21 Multimedia Framework standard. The idea behind this work [Koenen 2001] is that as digital multimedia spreads to many different platforms, transmission speeds increase and storage costs fall, digital rights management (DRM) becomes necessary to protect the value of content. MPEG21 is working on the definition of the Rights Expression Language (REL) and the Rights Data Dictionary (RDD) and on solving the problem of uniquely identifying digital content in a global way.

3.9 Metadata harmonisation initiatives

Although each of these initiatives claims to address different objectives and to cover different areas of the business, interoperability and mapping between different namespaces is an important issue in order to have a transparent flow of metadata through the whole chain and between content owners.

This need for integration is recognised in all the standard committees [Dekkers et al. 2002]. Since 2000, MPEG-7 Ad Hoc Groups have started to harmonise MPEG-7 and other schemes. In P_Meta special care has also been taken on the mapping between its Attributes and other schemes, namely SMPTE MDD and DMS-1, although their final purpose is somehow different [Hopper 2002]: MXF is intended to allow the interchange of finished material while P_Meta has a broader scope of metadata exchange and supports all business transactions even before any material exists; SMPTE MDD aims at supporting metadata in the domain of programme making in the broadcast environment.

Mapping between P_Meta and SMPTE MDD and DMS-1 is provided and Attributes not covered by SMPTE will be registered for inclusion into the dictionary. Table 3.13 presents some examples of mapping between SMPTE Frameworks and Sets and P_Meta Attributes.

Mapping attempts with DCMES are also provided by P_Meta and MPEG-7. The main problem that occurs is the difference in granularity as Dublin Core Element Set, being a simple content description model, has only 15 elements while the others provide a complex

Table 3.13: SMPTE and P_Meta mapping example

DMS-1 Set	DMS-1 Attribute	P_Meta mapping
Scene Framework	Scene Number	A148: ITEM_SCRIPT_SCENE_NUMBER
Production Framework	Integration Indicator	A225: ISAN_PROGRAMME_TYPE_CODE
Episode	Episode Number	A104: PROGRAMME_EPISODE_COUNT
Episode	Total Number Of Episodes	A96: PRG_EPISODE_QUANTITY
Rights	Copyright Owner	A83: ORG_NAME or S12: PERSON

structure and detailed information for Content description.

The mapping process consists of choosing the MPEG-7 or P_Meta descriptor which most closely maps semantically to each DC element [J. Hunter 2000]. Table 3.14 provides a list of the 15 DC elements and their mapping to MPEG-7 equivalent descriptor.

Besides mapping descriptors from different initiatives, hybrid approaches, which combine the complementary aspects of each of the solutions, have been proposed through the use of application profiles. Application profiles are schemas which consist of metadata elements drawn from one or more namespaces, combined together by implementers and optimised for a particular application [Heery and Patel 2000]. This approach requires each of the domain-specific metadata vocabularies to have an XML Schema representation of their elements in their respective namespaces. One such approach proposes the use of both DCMES and MPEG-7 metadata schemes in a application profiles that uses 5 main metadata components [Hunter 2002, 2000]:

1. DCMES – to specify the bibliographic information associated with the resource;
2. MPEG-7 MediaLocator Descriptor – to define the location of the resource;
3. MPEG-7 MediaTime Descriptor – to define the temporal attributes (start time and duration) associated with the resource;
4. MPEG-7 MediaFormat Descriptor – to specify the formatting and encoding information associated with the resource;

Table 3.14: Dublin Core Metadata Element Set mapped into MPEG7

DC Element	MPEG7 mapping
Title	CreationInformation.Creation.Title[@type="main"]
Creator	CreationInformation.Creation.Creator
Subject	CreationInformation.Classification.Subject
Description	ContentDescription.Creation.Abstract
Publisher	CreationInformation.Creation.Creator [Role/@term="Publisher"].Agent.Name UsageInformation.Availability.Dissemination.Disseminator- [Role="Publisher"].Agent.Name
Date	CreationInformation.Creation.CreationCoordinates.Date CreationInformation.Classification.Release[@date] DescriptionMetadata.CreationTime (date at which MPEG-7 metadata description was created) UsageInformation.Availability.AvailabilityPeriod (date, time and duration of broadcast or date of publication if availability is persistent)
Type	CreationInformation.Classification.Genre
Format	MediaInformation.MediaProfile.MediaFormat.FileFormat
Identifier	MediaInformation.MediaProfile.MediaInstance.InstanceIdentifier
Source	MediaInformation.MediaIdentification.EntityIdentifier
Language	CreationInformation.Classification.Language
Relation	CreationInformation.RelatedMaterial.MediaLocator
Coverage	CreationInformation.Creation.Abstract or CreationInformation.Creation.CreationCoordinates.CreationLocation or CreationInformation.Classification.TargetCountry
Rights	UsageInformation.Rights.RightsID

5. MPEG-7 TemporalDecomposition Description Scheme – to describe the temporal components (segments) of the video.

Working with XML Schemas and the XML Namespace mechanism, makes it possible that both simple Dublin Core-based searching can be done as well as fine-grained content-based using MPEG-7.

Similarly to what was done in other MPEG standards, MPEG-7 also groups its tools into MPEG-7-profiles and levels as a mean of simplifying the employment of MPEG-7 in different areas of applications enabling then an easier manner of harmonising and interoperate approaches. A profile defines a set of descriptors and description schemes that can be used in a certain interoperability context and a level gives the complexity

constraints within which the profile can be exercised.

A dictionary is another approach for facilitation the mapping between two standards. The MPEG-7 dictionary provides a flat list of elements together with all the related information as the type and the parent element.

Activities on mapping between SMPTE and MPEG-7 have been developed in two ways: 1) mapping both dictionaries and 2) mapping MXF DMS-1 and MPEG-7 MDS as presented in Table 3.15 [Rehm 2002]:

Table 3.15: SMPTE and MPEG-7 mapping

SMPTE	MPEG7
Framework	Description Scheme
	Profile
Set	Description Scheme
	Descriptor
Dictionary	Dictionary
Item	Descriptor
	Data Type

3.10 Concluding remarks

The metadata approaches presented in this chapter are thought to be the most important and recent developments on the definition of description schemes in the area of audiovisual systems. It is important to mention that it is not a complete survey of all the metadata initiatives for describing content — some others coming mainly from the traditional information systems and archivists world are also going on. However most of their results are incorporated in the solutions presented here or they cover aspects not related to video archiving. Just to mention some other important initiatives/organisations that were not addressed in this chapter we can mention 1) ISAD-G [ICA/CDS 1999] that provides general rules for archival description irrespective of the type of material and form of archive; 2) the International Association of Sound and Audiovisual Archives (IASA) Cataloguing Rules [IASA 1999] for the description of sound recordings and related audiovisual media and 3) the International Federation of Film Archives (FIAF) cataloguing rules [FIAF Cataloguing and Documentation Commission 1991] for film archiving.

Harmonisation between different metadata approaches is most of the times difficult or even impossible as they are intended for use in different areas of a broadcast facility and follow different approaches. Some mapping initiatives have been happening but until now achievements didn't lead to an universal solution.

The use of more than one scheme and the development of gateways at the interfaces of different systems is thought to be the best solution.

Chapter 4

Media Area Networking

Beside providing media enhancement through a set of normalised descriptor, supporting the main goals of a media asset requires the definition of architectures that enable the integration of several devices. An overview of the different approaches and technologies concerning the deployment of media assets in a networked environment is presented in this chapter. Two main lines are described: the current solutions provided by broadcasting equipment manufacturers and the IT solutions under development in the area of Storage Networking. The concept of Media Area Network is introduced.

4.1 Introduction

The solution for managing video content requires integrating several heterogeneous systems that are part of the core infrastructure. Making digital video items available through a network introduces the concepts of media and storage area networks whose main purpose is to make archived content available.

Different solutions have been proposed, making the integration of devices a complex issue. The solutions in broadcasting are essentially based on technologies that require the deployment of different networks: synchronous networks coexist together with ‘Command and Control’ and IT networks [Whitaker and Benson 2003; Watkinson 2001].

The increase of digital information has, in parallel, led to the development of solutions for improving the remote access to IT archives. These solutions, although not yet stabilized, are currently starting to be looked at as potential candidates to be implemented in television facilities [Reitman 2001]. This would be in accordance with the increasing

interest of using IT solutions in broadcasting environments.

4.2 Digital Networking in Broadcasting

The Serial Digital Interface (SDI) [ANSI/SMPTE 1997a] was defined as a method to transfer uncompressed digital audio and video between digital devices in broadcast and post-production environments.

With the introduction of compressed video formats, the use of SDI requires the uncompressing of the signal at the output of the source device and the recompression at the input of the target device. The Serial Data Transfer Interface (SDTI) [SMPTE 2005] was developed to provide mechanisms for exchanging audiovisual signals in compressed formats.

4.2.1 Serial Digital Interface

SDI uses coaxial cable as the physical support and is designed to transport synchronously uncompressed digital video using 10 bit words. Both composite and component video signals are defined and the bit rate is determined by the clock rate of the digital data: 143 Mbps for NTSC, 177 Mbps for PAL and 270 Mbps for Rec 601 4:2:2 component signal are defined; the widescreen component system produces a bit rate of 360 Mbps.

The words are serialized and the data is scrambled and encoded. At the receiver, the inverse algorithm is used to recover data. Scrambling assures a large number of transitions that enable a reliable clock recovery.

Synchronisation between the transmitter and the receiver is provided by the **SAV** (Start of Active Video) and **EAV** (End of Active Video) sync patterns contained in the data as presented in Figure 4.1 for 270 Mbps and 360 Mbps operation modes.

The area between **EAV** and **SAV** can be used to transmit ancillary data such as embedded audio, error detection and control, etc.

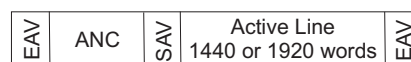


Figure 4.1: Basic SDI 4:2:2 bitstream

Although it is a point-to-point serial unidirectional connection, deploying a network

is possible through the use of an SDI router that interconnects different devices such as video servers, VTRs, non linear editing (NLE) workstations, etc.

4.2.2 Serial Data Transfer Interface

SDTI shares the physical layer and the basic data structure of a SDI bitstream (Figure 4.2) enabling both solutions to co-exist and the re-use of existing SDI cabling and equipment available in a broadcaster facility.

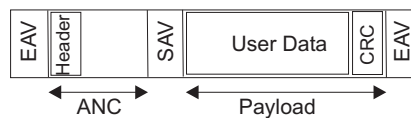


Figure 4.2: SDTI signal format

SDTI uses the ancillary data space to identify that a specific line carries SDTI information. A 53 word header is used to identify the data ID (140h for SDTI), the data type of the payload (e.g. MPEG-2 TS, DVCPRO, etc), the source and destination addresses and other information such as a checksum and the line number. The rest of the ancillary data space is available to carry other data.

The IPv6 addressing scheme (128 bits) is defined for SDTI, allowing the networking of different devices.

The data stream is used to transport any packetised data signal over the active lines allowing 200 Mbps of payload capacity in a 270 Mbps SDI system and 270 Mbps in a 360 Mbps link.

Besides avoiding the need to uncompress and re-compress the digital stream, SDTI provides other advantages that include the transmission of data faster than real time or the possibility of multiplexing different streams in the same link. In a 270 Mbps SDI environment, with a payload of 200 Mbps, a 50 Mbps compressed stream can be transmitted at four times real time or, alternatively, four different streams can be transmitted simultaneously.

Having as support SDI, SDTI is an unidirectional interface without re-transmit capabilities for corrupted data. Consequently, SDTI packets can be corrupted and protecting mechanisms as FEC (Forward Error Correction) are used to overcome this problem.

Both these interfaces are used primarily for video transmission. Other type of information requires a different type of support and the implementation of different networks.

4.2.3 SDTI Content Package Format

Due to the increase requirement of transporting video associated information, SMPTE defined the ‘SDTI Content Package Format’ (SDTI-CP) [SMPTE 2000a] which aims at transfer video, audio, data and metadata over SDTI.

Each ‘Content Package’ (CP) is constructed of up to four ‘Items’ each comprising one or more ‘Elements’. The possible Items are 1) System, 2) Picture, 2) Audio and 4) Auxiliary as presented in Figure 4.3. This group of standards define the structure of the content package mapped into SDTI operating at 270 Mbps and 360 Mbps and the formats of element and metadata [SMPTE 2004a].

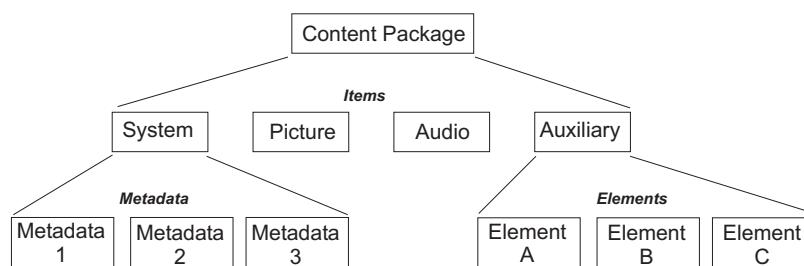


Figure 4.3: Basic SDTI-Content Package structure

The auxiliary item in the CP is used to transport data content as teletext and subtitles while the system item can be used to carry metadata for the package as a whole (e.g. the programme title) or metadata associated with any of the other three items in the package. A linking scheme that allows the unique association of a metadata item with its associated element is provided. The metadata contained in this system item can be a replication of the metadata embedded in the corresponding element, so that quick access to information is possible without having to parse the element bitstream, or additional information not available in the element [Wilkinson 2000].

The CP format can be mapped into a file structure for the exchange of program information between disc servers.

The SDTI-CP format is then an attempt, coming from the broadcasting world, of providing methods for enabling the share of the same network to transport video and

associated audio, data and metadata.

4.3 Network Storage Models in the IT world

The definition of network architectures and technologies specific for storage have recently been, with the increase of information that needs to be accessed and shared, object of interest of researchers and industries.

One of the difficult aspects on the implementation of storage networking is the proliferation of protocols and attachment techniques. Examples of different approaches are the concepts of *Direct Attach Storage* (DAS), *Network Attach Storage* (NAS) and *Storage Area Networks* (SAN) [Monday and Connor 2001; Anidi and Nujeeerale 2002] when considering the network topology and the supporting technologies for attaching storage to the servers.

4.3.1 Supporting Technologies

Some approaches have entailed the development of specialised networking protocols such as SCSI (Small Computer System Interface), Fibre Channel (FC) [ANSI 1994] or, more recently, Infiniband [Association 2002]. Although SCSI, one of the first solution for storage networking, can support gigabit transfer rates, it presents limitation both on the distance (a few meters) and the number of devices that can be attached to a controller. Fibre Channel and Infiniband were developed to overcome these limitations and, as most network approaches, use the layered concepts of the OSI stack, specifying functionalities equivalent to the OSI four lower layers.

The FC network is made up by one or more bi-directional serial data channels that enable different data rates that can go up to 2 Gbit/s, can be implemented using optical fibres or copper wires and can cover distances up to tens of kilometers. Fibre Channel networks can be configured as 1) point to point links, 2) switched networks through the use of a FC switch (named ‘Fabric’) or as a 3) ring topology connecting nodes directly to each other.

Infiniband, developed by an industry consortium, provides storage networking through point-to-point interconnections operating from 2.5 Gbit/s to 30Gbit/s. Switches provide the deployment of complex networks. By allowing applications to transfer data directly from the network card into the application, it is intended to improve the FC solution.

These technologies are used to implement different topologies for storage networking.

4.3.2 Network Topologies

DAS is the traditional mechanism for attaching storage to hosts — storage devices are attached directly to a host using a cable-based bus like SCSI. As the need of storage and servers grows, this approach presents limitations on the number of storage devices that can be attached and on the distance of the storage devices from the server.

NAS and SAN configurations decouple storage from a single host and storage devices are assumed to be independent machines that provide storage services via a network to a number of host servers.

While NAS storage tends to use existing LAN infrastructures, SAN uses networks specialised for storage traffic. A NAS device is basically a file server that can be mounted remotely and accessed over a network using traditional remote driving assignment like the Network File System (NFS), instead of residing on the application server. The storage device shares the same network resources as the client/servers that reside in the same network. In the SAN model, storage is made available through dedicated networks like FC.

While for DAS and SAN topologies block level Input/Output (I/O) is used for all the operation of accessing a file, NAS does file-level I/O: 1) the NAS device is given a `File Handle:Offset` request; 2) the device file system processes and resolves the request to a block in the disk device; 3) the NAS device uses block I/O to access the disk device. This operation is illustrated in Figure 4.4.

The processes of each of the solutions can be summarised as:

- DAS:
 1. Application makes file I/O request to FS in the server;
 2. File system initiates block I/O to disk.
- NAS:
 1. Application Server directs file I/O request over the LAN to remote file system in the NAS appliance;
 2. File system in the NAS appliance initiates block I/O to NAS integrated disk.
- SAN:
 1. Application makes file I/O request to FS in the server;
 2. File system initiates block I/O to SAN attached disk.

The downside to these dedicated architectures is the price and the increase of management difficulty:

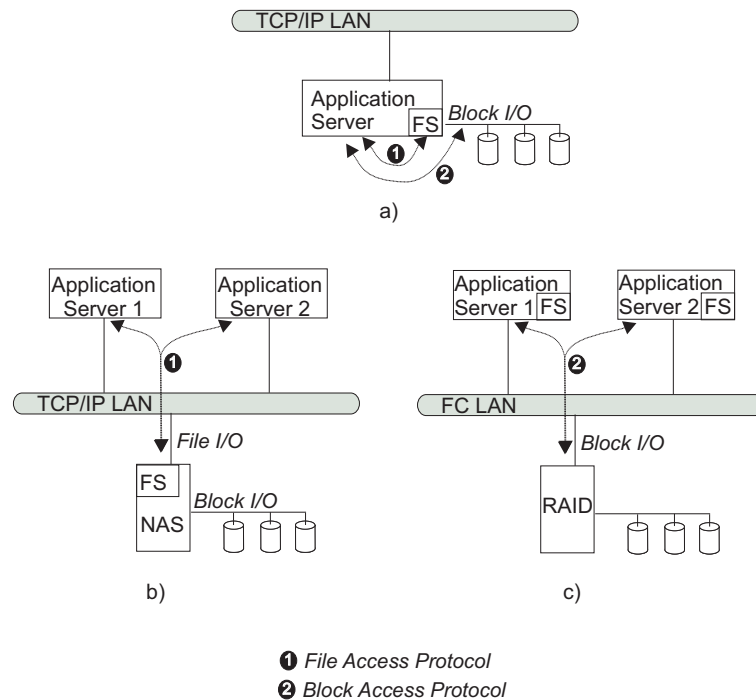


Figure 4.4: a) DAS b) NAS and c) SAN architectures

- i. by purchasing FC switches from two different companies, different management consoles will be used requiring different expertise;
- ii. dedicated adapters, switches and wiring to equip the network are needed and the cost of these components tends to be higher when compared to Ethernet network elements;
- iii. these specialised networks have very limited support for wide area networking and security. Accessing information over long distances requires an IP network bridge.

4.3.3 SAN-IP Storage Technologies

The distinction between the different models presented is however not as clear as it might seem. Although the initial approach for the SAN topology has been based on SCSI and Fibre Channel, the advent of IT networking infrastructures capable of gigabit speeds is making Ethernet based IP network a solution to consider. The convergence of NAS and SAN, mainly differentiated as IP based or not IP based solutions, is happening through

the development of some new IETF standards:

- i. FCIP (Fibre Channel over IP) [Rajagopal et al. 2004] — a standard for encapsulating and tunnelling FC over an IP network. The main objective of this approach is to provide mechanisms to bridge FC-SAN islands across a TCP/IP backbone by encapsulating FC frames into IP packets that are tunnelled through an IP network to the remote SAN. At the remote site, packets are disassembled and handled as local FC-SAN traffic.
- ii. iFCP (Internet Fibre Channel Protocol) [Monia et al. 2002] — a gateway-to-gateway protocol for attaching existing FC devices into an existing IP network. The gateway terminates the FC session, establishes a TCP/IP session and provides FC to IP mapping through address translation (from 24-bit FC addresses to the IP address of the remote gateway plus a 24-bit address of the device beyond the gateway). This solution maximizes the use of IP networking and enables the replacement of FC switching and routing elements by TCP/IP components.
- iii. iSCSI (SCSI over IP) [Satran et al. 2004] — a standard for transporting SCSI packets over TCP/IP. Each resource supports an IP interface and the iSCSI stack that provides encapsulation and disassembling of SCSI commands into IP.

Figure 4.5 illustrates the differences between these three protocols in what concerns to the network infrastructure, connection of devices and switching/routing technologies.

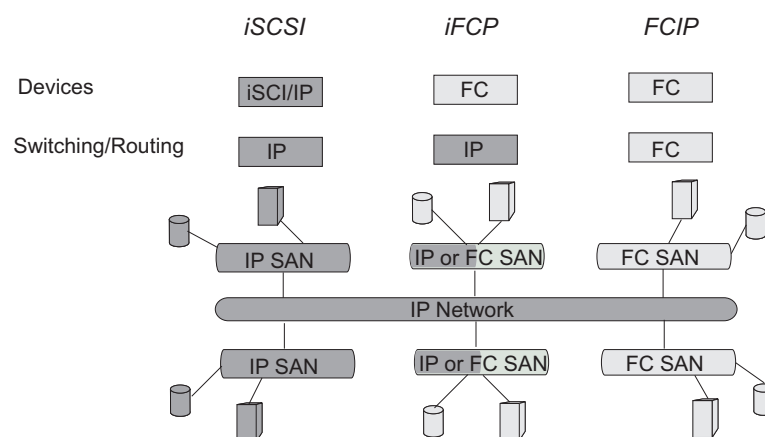


Figure 4.5: IP storage protocols

4.4 SNIA Terminology

Although there was an attempt to make a distinction between different technologies and topologies for storage, this distinction is not clear as there are overlap and convergence of different approaches.

The Storage Networking Industry Association (SNIA) [SNIA b], a non-profit trade association, provides a definition of the term SAN which is not specifically identified with Fibre Channel technology. SNIA encourages the use of a qualified phrase such as ‘Fibre Channel SAN’ to specify a technology. According to their definition, an Ethernet-based network whose primary purpose is to provide access to storage elements would be considered a SAN.

The terms ‘Storage Area Network’ will be used in the rest of this document according to the SNIA ‘Dictionary of Storage Networking Terminology’ [SNIA a]:

Storage Area Network A network whose primary purpose is the transfer of data between computer systems and storage elements and among storage elements. A SAN consists of a communication infrastructure, which provides physical connections, and a management layer, which organises the connections, storage elements, and computer systems so that data transfer is secure and robust.

or

A storage system consisting of storage elements, storage devices, computer systems, and/or appliances, plus all control software, communicating over a network.

4.5 Media Networking

Storage networking in a broadcaster facility provides the means for deploying MAM systems that provide remote access to archives. This new concept that brings together the SAN characteristics defined above and the facilities provided by a MAM will be defined, in the context of this thesis, as a ‘Media Area Network’ (MAN):

Media Area Network The set of processes, systems and tools needed to manage a MAM in a SAN environment.

This definition is intended to be sufficiently broad to include different solutions of networks, applications and devices.

4.6 Concluding remarks

Media and storage networking in a broadcaster environment is a problem that has been raised with the introduction of digital operation.

Two independent working lines have been developed: 1) some solutions coming from the traditional broadcast world and 2) several approaches from the IT market.

In the broadcast environment, different networks have been implemented for the transfer of video and associated metadata, data and command and control leading to inefficient workflow processes and to the increase on the cost of the infrastructure.

The solutions proposed by the IT community for storage networking are still being developed. The standards are expected to provide mechanisms to solve the problems of interconnecting multiple system platforms and to unify the management.

Chapter 5

VIDION – Implementing a Case Study in RTP

This chapter presents the architecture of a MAM system developed within the research context described in the previous chapters. The main components of the system are introduced and architecture decisions are justified according to the current scenario.

5.1 Introduction

The present situation of the television archives and the need to urgently define mechanisms for reducing tape handling in the archive, intensive staff work, distribution of unwanted media by allowing users to preview selected material, and the need for enabling faster documentation and to provide the technical basis for electronic commerce and re-purpose of archive material, led to the development of a system in the area of Digital Media Asset Management to be used by RTP (the Portuguese Public Television Broadcaster).

Proprietary solutions available in the market failed to provide a complete answer to the problem and did not offer guarantees of continuous evolution. Furthermore, they didn't fulfil the low cost criterium required by Broadcasters. The VIDION (Digital Video On-Line) project [Viana and Silva 1998; Viana et al. 1999; Sequeira and Viana 2001] main objective was to develop an open and low cost system for television audiovisual archives that would solve the problems stated and would allow the definition of workflow procedures based on the archive. Moreover, it was expected that the use of digital technologies would

open new roads to the public access using the Internet. The project should exploit the convergence of television, computer and telecommunication technologies and develop a platform based on generic IT technology integrating the annotation, searching and editing chain using a unique network that should be able to transfer essence, metadata and control commands.

By associating essence (audiovisual content) with metadata and making both available through a network, integrating the process of media ingest, annotation, archiving, searching and editing, VIDION provides not only a tool for the efficient management of video archives but also a platform for improving the flow of information inside media company premises and innovative working methods.

Two exploitation scenarios are foreseen:

- a. in-house use, where the system provides mechanism for organising the vast audiovisual archives with advanced video annotation and retrieval mechanisms improving a broadcaster operation;
- b. content selling via the online service to external customers.

The in-house or external end-users may comprise journalists, audiovisual and multimedia producers, researchers, programmers, cultural and educational organisations and individuals.

5.2 System Architecture

Using the broad definition of SNIA presented in Section 4.4, the system developed is a Storage Area Network (SAN) as it is a storage system composed of a set of elements communicating over a network. It is oriented towards the management and exploitation of television archives but flexible enough to accommodate requirements from any other content owner that needs to store, manage and efficiently access video content for repurpose, research or business by providing the functionalities required by a MAM, as defined in Section 1.4. The system fulfills then the requirements for being a Media Area Network (MAN) as defined in Section 4.5.

The solution developed contrasts with the usual solutions proposed/used in broadcast environments. System architecture builds on generic and open protocols and interfaces and can take advantage of intrinsic features of some network technologies. The exploitation

of these architectural concepts allowed the implementation of a modular, flexible and low-cost system based on IT technology to which new features can be added as required. This differs from the proprietary solutions that make use of expensive and specialised equipment.

This section presents the proposed VIDION system architecture in terms of buildings blocks, application modules, middleware and main functionalities.

5.2.1 System Main Elements

VIDION project defines an architecture for a digital media asset management system consisting of a number of sub-systems and different types of archives depending on the quality of the material archived and on its accessibility. All the components, connected through a network, set up a system that makes possible the efficient access to on-line video material and enables its re-use. On the next sections, a description of some of its components and requirements as well as an overview of the whole architecture will be presented.

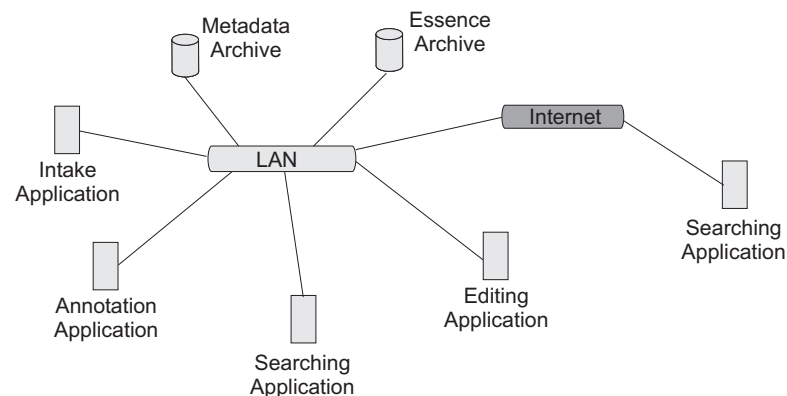


Figure 5.1: General architecture of the VIDION system

The system developed within VIDION is composed by a number of elements interconnected through a network as shown in Figure 5.1:

1. Metadata Archive
2. Essence Archive (Audiovisual Material)
3. Intake Application

4. Annotation Application
5. Browsing Application
6. Editing Application

5.2.2 The Essence Archives

Developing a networked television archive raises some problems due to the large amount of information that has to be stored and transmitted. At present, storing and networking technologies impose some conditions on the definition of video formats as compressed video can range from some hundred Kbps to tens of Mbps; [EBU/SMPTE 1998] and [EBU 2001a] recommend different video compression schemes depending on the application area. System developers and managers have to be aware of storage and network bandwidth as well as end-user terminal performances. Due to these problems VIDION defines archives which support different video qualities and have different accessibility.

Accordingly to the quality of the video, three different archives are defined:

1. Full Quality Archive
2. Browse Quality Archive
3. Internet Archive

The *Full Quality Archive* is indispensable in the system as it is the one that keeps the original video copies in a format that can be used for a professional production of a new item. Although VIDION suggests the use, in this archive, of MPEG2 format as it is the one to be used in digital television, the system supports any other kind of analogue or digital formats either compressed or decompressed.

Due to processing, bandwidth and storage requirements, the regular use of full quality material would imply the use of very expensive equipment, making such a system unfeasible. To overcome this difficulty, VIDION defines a *Browse Archive* where lower quality copies of video are made available, through the network, to all the system workstations. Remote searching, previewing, selection and editing operations are then technically and economically feasible as no decoding hardware nor complex networks are required for working with a video quality still acceptable for these types of activities.

Putting media assets in the Internet is a key factor for making information, which has an important cultural and economical value, known. VIDION enables the access to

selected parts of the intranet archive in a very low quality copy. Search and manipulation facilities are reduced in this service.

Accordingly to its accessibility, three different archives are defined:

1. On-Line Archive
2. Near-On-Line Archive
3. Off-Line Archive

The facility of accessing video material decreases from the *On-Line* until the *Off-Line* archive, making the slot of time needed since the user requests an item until he/she gets it, progressively larger. Cost per hour decreases while storage capacity and permanence increase from the on-line to the off-line systems.

Although ideally real-time on demand access to all video clips would be desirable, costs and technology still don't allow a complete magnetic disk archive solution. To solve the problem, robotics datatape libraries for the Near-On-Line Archive or conventional on the shelf tapes for the Off-Line Archive, are used. Remote operation of robotic datatapes may enable the automatic transfer of material from the Near-On-Line to the On-Line Archive.

5.2.3 The Intake Application

The *Intake Application* is used for the pre-processing of the material to be imported in the VIDION system. This pre-processing provided by the *Intake Application* consists of the following steps:

1. Material Identification: a unique identifier to the material that is to be imported into the system is specified. This will provide the mechanisms for linking all the versions of the same content.
2. Material Digitisation: material available in analog formats is digitised for further processing. Different versions of the content are produced using pre-defined parameters or user defined ones.
3. Material Analysis: pre-processing of the input stream enables the automatic extraction of information about the content. Examples of implemented operations are DVB and MPEG metadata extraction and keyframes generation. A documental number that identifies this automatic process is linked to the metadata

to enable later analysis and validation of the data¹.

5.2.4 The Annotation Application

The *Annotation Application* provides the mechanisms for metadata introduction related to the material to be indexed by the system. The result of this process is a set of metadata elements that includes textual and non-textual data according to the DS defined (Section 5.4). This metadata is stored in the Metadata Server.

Different levels of annotation are supported accordingly to the hierarchical level of the material and to the requirements imposed by the archive and end users. Authorized users can upgrade, at any time, the amount of metadata associated to a stream allowing a continuous refinement of information stored in the database.

The results of the automatic documentation process are presented to the documentalist so that they can be reviewed, validated and manual additions and corrections can be introduced. These operations are supported by a set of services as described in Table 5.1.

5.2.5 The Browsing Application

VIDION *Browsing Application* offers a set of tools that manage the interaction of the user with the system through a set of services:

1. Query and Navigation services, that provide the mechanisms to obtain the identifier of the required content and to navigate within or among different streams;
2. Retrieval services, that provide the mechanisms to show and retrieve the selected content at different levels of quality and detail;

Due to the complexity and expected dimension of such a system, the searching options can range from hierarchical and hyper-linking navigation and keyword searching, to powerful structured queries constructed by the user through a graphical interface based on a tree. Search refinements and cross methods are also available (Table 5.2). External users connected to the service face restrictions on the search functionalities available and on the material delivery service. In both versions, very little processing is required for enabling applications to run on standard machines.

¹The system developed doesn't provide tools for complex characteristic extraction as that is out off the scope of the project. However external tools can easily be integrated in the system as explained later

Table 5.1: Annotation application services

Service	Description
<i>Metadata Services</i>	
Validation	Provides mechanisms for user identification and validation. Different privileges are provided to the user depending of the result of this operation.
Archive Browse	Enables browsing the archive and the available items.
Metadata Edition	Returns the <i>Metadata Edition Screen</i> that enables the introduction of metadata using the available fields as defined by the DS.
Copy/Support Control	Provides the mechanisms that enable multiple copies of the same content to co-exist and to be associated with the correspondent physical supports.
Assisted Annotation	Provides functionalities that enable the automatic selection of a set of Ds from a thesaurus
Metadata Update	Updates the entries in the <i>Metadata Archive</i> . It provides also the mechanisms for validating automatically extracted metadata.
<i>Content Services</i>	
Preview	Enables video streaming of a selected item.
Content Process	Enables the use of tools for processing the content to extract information as timecodes or keyframes.

5.2.6 The Editing Application

Non-linear editing and EDL generation allows the creation of new video clips based on search results allowing the re-use and re-purpose of archived material. The purpose of this application is to provide a mechanism to produce draft versions of new clips based on the browse quality content. Table 5.3 presents the main services provided by the *Editing Application*.

5.3 Core Technologies for Media and Metadata Access

Increased flexibility and elimination of some of the drawbacks of a complex system like a MAM system can be achieved by the use of technologies that enable transparent creation of a distributed system and a three-tier architecture.

The efficient access to streams and metadata depends on the transparent distribution

Table 5.2: Browsing Application services

Service	Description
<i>Browsing and Navigation Services</i>	
Validation	Provides mechanisms for user identification and validation, client type identification and asset selection.
Index Search	Provides the list of available search fields that will be used to edit the query and presents the <i>Search Screen</i> . This list is dependent on the type of client used.
Browse Search	Returns the thematic trees used to browse the archive. Stream content classification according to the DVB program classification is used together with a list of descriptors that narrow down the search to a feasible set of results.
Search Edition	Returns the <i>Query Edition Screen</i> that enables a query composition.
Cross Search	Creates a container of a search process and enables the application of any searching service to the container content.
Browse Results	Enables browsing the results of a previous search process to make other queries and obtain related content.
<i>Retrieval Services</i>	
Results	Returns the <i>Results Screen</i> with a list of hits matching the query. Results are represented by icons and a short description.
Result Detail	Enables the access to detailed information about the results. Can call the Browse Results service to navigate through related items and obtain more results.
Preview	Enables video streaming.
Export	Exports the selected results.

of streams and services that deal with data processing and control.

Within VIDION and ATLANTIC [ACTS/AC078 1999], a CORBA based framework was developed to allow the deployment of distributed services [Viana et al. 1999; Ferreira et al. 1999] in television environments.

5.3.1 The CORBA Technology

The Common Object Request Broker Architecture (CORBA) [OMG 2002] is a standard for transparent distribution of services and run-time system reconfiguration.

Based on the ‘Remote Procedure Call’ (RPC) concepts, CORBA introduced some new functionalities which enable the remote invocation of objects, hiding the implementation

Table 5.3: Editing Application services

Service	Description
Import	Imports data from the <i>Browsing Application</i> .
Export	Exports the results in the form of an EDL or working document.
Edit workspace	Selects the appropriate edit workspace depending on the input streams format (multiplexed or not).
Preview	Enables video streaming.

details and object location. Through the use of CORBA services, some of the traditional client-server applications drawbacks, such as server failure, client application dependency on server location, underlying technology (operating system, network, programming language, etc) dependency and complex system reconfiguration, are overtaken [Vinoski 1997].

CORBA standard interface for software components, the Interface Definition Language (IDL), enables the communication and integration of modules written in different languages and running on top of different operating systems and hardware. Besides that, the definition of a standard protocol for inter-ORB, the main CORBA element, communication — the Internet Inter-ORB Protocol (IIOP) — makes the interoperability between different ORBs possible.

CORBA defines a set of object services, two of which are important for this context: the *Naming* and the *Trading* Services. The first is a directory service that translates names into objects: objects are published along with a descriptive name and users browse the service to select the desired ones. The latter is similar but searches are based on properties of the objects instead of names.

These services enable the translation and location of objects in the system through the use of a directory service that translates names into objects. This allows the system manager to re-configure the system without client applications being aware of any change as they have no need to know to which server they have to connect to, but just to make a request to a service which gives the client all the information it needs to make a remote method invocation (Figure 5.2). This ‘object ignorance’ makes it full transparent to the client whether it is using a local or remote resource as each CORBA object has an unique reference or identifier handler that remains valid even if the location of the object changes (unlike network addresses).

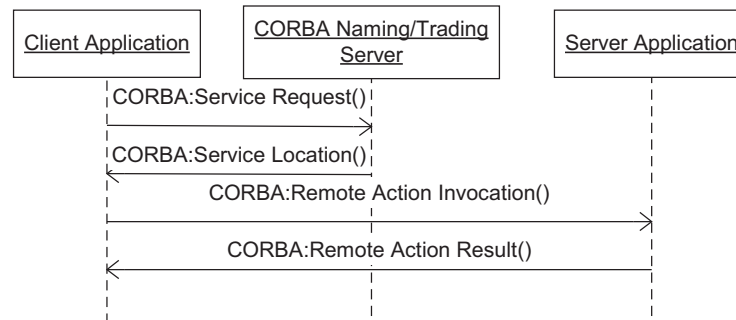


Figure 5.2: Use of CORBA Services for application location

When talking about large-scale television archives which are, by nature, distributed, the use of CORBA technologies can then introduce benefits for software developers, system managers and end-users.

5.3.2 Middleware in VIDION

The transparent distribution of services within a broadcast archive can be achieved by the use of CORBA Naming and Trading Services. The naming service is appropriate when the user wants a particular object and can refer to it by its name. The trading service allows the user to search, not for a particular instance of a service, but for one that performs what is required, allowing also advanced features like load balancing to be performed automatically. These services can be used within a studio to allow an easy browsing and selection of the available studio services.

Client applications have no need to know to which server they have to connect to, but just to make a request to the appropriate CORBA service which gives all the information needed by the client to make a remote method invocation of an available service (e.g. a restoration module in the intake workstation).

VIDION tested the used of CORBA for locating available services and streams. This configuration enables a run-time re-configuration and distribution of the services, without notifying the clients, every time the load of the system justifies or new functionalities need to be introduced. An example is the extension of the system to add a new module for video segmentation and video information extraction. When a new incoming stream

is detected, the system just has to contact the CORBA Services to know which of the metadata extraction services are available.

The use of a three-tier architecture for metadata access can also be enabled by the use of CORBA. VIDION proposed [Viana et al. 1999] the use of CORBA and Java Remote Method Invocation (RMI) to overcome the problems of DBMS dependency: any access to the database can be done using CORBA remote invocation of methods that implement the entire upload and download of metadata. Besides making the client code simpler, this approach enables the evolution of ODBC to native methods for accessing the database.

5.4 VIDION Description Scheme

As discussed in Chapter 3 different approaches have been followed for the definition of a standard Description Scheme for audiovisual material. All these approaches are, or were during the development of this prototype, still not stable. Convergence and total mapping is not expected to happen due to the differences of purpose of each of the initiatives. MPEG-7, coming from the multimedia world, is expected to face some difficulties on imposing itself as the standard in broadcasting as other initiatives brought to discussion cover different areas of a broadcaster operation.

However, despite their differences, most of them have some similar proprieties. The Video Description Scheme defined for VIDION followed some of the basic ideas and recommendations of the work under development in the different organisations. As it was developed in parallel with the international activities in this area, some of the VIDION DS proposed solutions are also reflected in the current versions of these standards.

As described in Chapter 3, two streams have been followed: to have a flat list of metadata elements — as the SMPTE MDD (Section 3.7.1) — or to have metadata structured in a model — as MPEG7 (Section 3.8) or DMS-1 (Section 3.7.2). The VIDION naming conventions for the proposed solution for metadata in broadcasting environments matches those of MPEG-7: Descriptors are the metadata elements and Description Schemes are the structures grouping Descriptors and providing relations between them.

A generic model targets to a wide range of applications and domains and, therefore, mechanisms that allow specific domains to make use of just part of the model are needed. In order to reduce complexity of the system and to customise it to the final user, a definition/selection of a set of Ds can be provided. This concept of *Profiling* is starting to be used in MPEG-7 and the proposal in this thesis can also provide this functionality.

Special care was then taken on designing a flexible scheme and on re-using metadata. Examples of information that can make the television archiving process more efficient are:

- i. IPR information;
- ii. Trace of material request;
- iii. Support of DVB information;
- iv. Tracking of stream duplication.

The VIDION DS emphasises some aspects considered fundamental in video description for the broadcasting environment:

- a. The structural hierarchy: video streams are naturally regarded as structured in several levels that correspond to their organisation along the intrinsic time line.
- b. The archival features: video documents, in spite of their peculiar features, are also the subject of archival activity. It is necessary to take into account the common requirements of archives and the specific features of the medium.
- c. The creation features: each video stream results from a conception process which has associated information that can not be directly extracted from the content itself.
- d. The usage information: the past use, the right holders or the availability of the content are aspects that shall be linked to the essence as they provide information that can help on the asset management.
- e. The location: multiple instances of the same content can co-exist in different supports. Locating and relating all of them should be possible.
- f. The spatio-temporal segmentation: MPEG-4 [ISO/IEC 2001] established the grounds for a video structure that encompasses object identification. This richer semantic account should have a counterpart in the metadata and was considered by MPEG-7. Although not implemented in the current version of the prototype presented in this section, the extension of the scheme to provide this features was considered [Torres et al. 1999].

These aspects should not be looked as independent, mutual-exclusive or dealt by different people or departments, but as a one: metadata multiplexed in a video stream

transported over a network can be extracted from the archive or automatically inserted by the equipment used to process the stream.

This model was validated by end users in broadcasting environments in several demonstrations and hands-on workshops.

5.4.1 Structural hierarchy

The descriptions of a video stream or a set of video streams can be organised according to well-defined temporal hierarchies. This hierarchy reflects several possible divisions of the video content being described in time intervals. The higher the level in the hierarchy the larger the time interval considered.

In a structural division strategy for video description, a set of principles are usually followed in order to make the annotation/indexing and searching tasks more efficient:

- i. Avoid the repetition of information in the different levels;
- ii. Move common description information in lower levels descriptions to a single upper level description in the hierarchy (the descriptors associated to a VideoDescriptionUnit are general and common to all levels of a possible hierarchy);
- iii. Adopt a flexible hierarchy to allow the creation and change of structural schemes;
- iv. Capture a core of descriptors common to all levels so that it is possible to refine a description when we are moving down the description hierarchy.

One of the key points of a video DS is the flexibility that should be possible for defining new hierarchies. However, some care should be taken not to make the extraction and understanding of the metadata too demanding for the equipment used. As mentioned before, some of the possible hierarchies are well known and already in use in different areas. This fact should be used to make a small set of normative schemes based on these already accepted video organisations. The DS should however be able to be easily extended both for new normative and proprietary solutions.

A commonly established hierarchy is the one used to classify films: several sequences, that compose the film, can be identified and each sequence is further divided into one or more shots as illustrated by the class diagram in Figure 5.3.

VIDION proposes a hierarchical video DS illustrated in the class diagram of Figure 5.4, based on the usual material organisation of news programmes in the broadcasting industry.

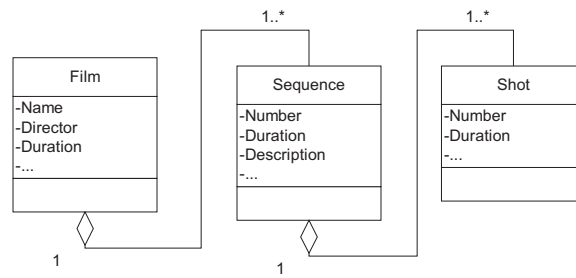


Figure 5.3: Three level hierarchy for Film description

This hierarchy can easily be adapted to the shorter one presented in Figure 5.3 or can be enlarged to include some more levels.

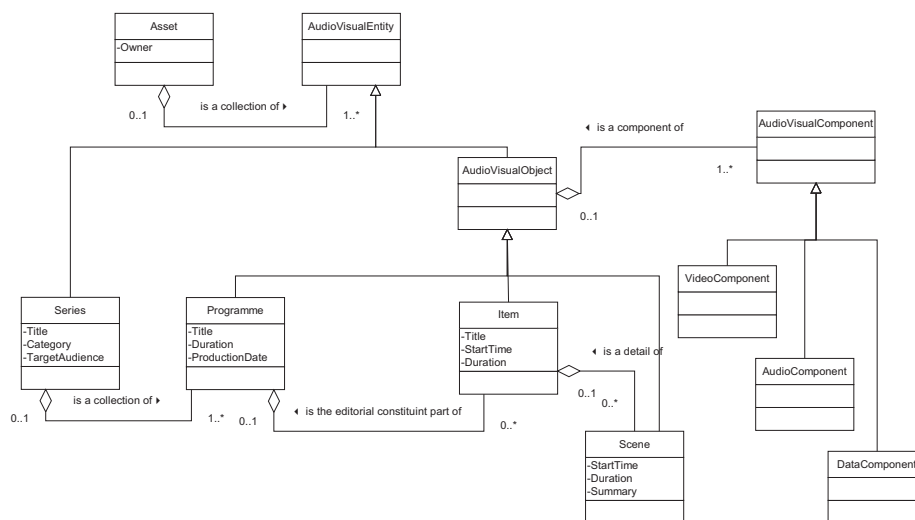


Figure 5.4: VIDION Proposed Temporal Hierarchical

Each of these hierarchical levels has attributes of their own, but the lower ones inherit the attributes from the ones immediately above:

- A **Series** consists of a set of one or more finished **Programme** grouped together by a common theme. An example could be an ‘Evening News’ series. It can have one or more authors, a classification type and a target audience.
- A **Programme** consists in a single programme meant to be transmitted completely

and without interruptions. An example can be the ‘Evening News of 01/01/03’. It is made by the sum of one or more **Items**, has an associated production data and can exist in multiple copies. Each **Programme** can be broadcasted more than once. **Programme** classification is dependent on the **Series** it belongs to.

- An **Item** is the main section inside a program with a common theme. Example: The ‘Fireworks news in Evening News of 01/01/03’. It has a technical staff, one or more authors, can have a character interpreted by an actor, a translator and can contain some **Scenes**.
- **Scenes** are usually very short, have a title and a small description. They can be used to mark any particular detail that can be relevant to the future such as a goal in a football game or a close-up of a personality.

The hierarchy proposed in the VIDION DS conforms with the recommendations defined by most of the metadata initiatives as P_Meta, DMS1, MPEG-7 and ISAD. Although some of them don’t specify the decomposition of an entity in segments (as MPEG-7 that provides an abstract type — *SegmentDecomposition* DS — that represents an arbitrary decomposition) or provide different levels of decomposition, mapping between concepts is possible as illustrated in Section 5.7 for P_Meta.

The segmentation of a **Programme** in its components through a timeline is represented in Figure 5.5. As it can be seen, a **Programme** is the sum of its **Items** — a new **Item** starts immediately after the previous one and the total duration of all the **Items** equals the duration of the **Programme**. This structure reflects the syntax and semantics of a television programme which can have no overlaps or gaps in the narrative.

Due to the meaning of a **Scene** in the VIDION DS, other relations than the one described above are possible. Overlaps and gaps between the **Scenes** that are part of an **Item** are possible. However, due to its definition, a **Scene** belongs to just one **Item** in the same **Programme** meaning that it is not possible to have one **Scene** that goes beyond an **Item** limits.

5.4.2 Thesaurus

Some of the Ds in each of the hierarchy levels are human dependent. To reduce the risk of not having the adequate describing keywords, a thesaurus, containing a controlled vocabulary list of terms and keywords to help on defining information accurately and

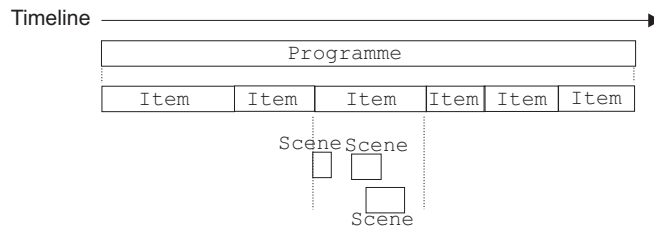


Figure 5.5: VIDION Programme stratification

finding information faster, was defined and used. In the current implementation, these pre-defined Ds are associated with the **Item** and **Scene** levels of the hierarchical organisation of a video stream.

The structure of this thesaurus follows the requirements of the prototype end-user (RTP) and is structured in an hierarchy of themes and sub-themes to which pre-defined Ds belong [Goncalves 1999]. Fixed types of associations among descriptors in the thesaurus enable navigation and term selection by showing relationships between terms that are close in meaning.

Table 5.4: Types of relations between descriptors in the thesaurus

Type of Relation	Relation	Description
<i>Hierarchy</i>	ST	Specific Term
	GT	Generic Term
<i>Association</i>	RT	Related Term
<i>Equivalence</i>	UF	Use for
	USE	Use this term instead

Table 5.4 presents the set of possible relations between Ds. The possible relations are of *Equivalence*, *Hierarchy* and *Association*:

Equivalence : this relation is used for relating synonyms and to provide a unique descriptor. An example could be

Seashore USE *Coast*

Coast UF *Seashore*

Hierarchy : an organisation of Ds in different levels that enable the definition of clear contexts. An example is

Accidents in Football **GT** *Sport Accidents*

Sport Accidents **ST** *Accidents in Football*

Association : provides some possible relation between two Ds so that the description can be more precise or the topic is enlarged.

Disaster **RT** *Catastrophe*

Table 5.5: Relations with the descriptor Olympiads

☐ GT Olympiads
☐ USE Olympic Games
☐ RT Olympic Village
☐ RT Olympic Delegation
☐ ST Olympic Torch
☐ ST Olympic Winter Games

Modifying the thesaurus structure and content has no implication on the architecture and software modules of the system.

Using the thesaurus to guarantee accurate annotations can be put into practice by two different ways: 1) the documentalist searches the list of terms and manually selects the ones he is interested in or 2) the documentalist asks the system to propose a list of possible terms. The second approach is possible through the use of a tool that checks the terms used in the free style descriptions and, based on previous annotations, selects the ones that were previously used for the same vocabulary.

5.4.3 Metadata Re-use in the Context of DVB

The problem of re-using metadata produced in different parts of a television chain is a key aspect on the success of the future television operator. Broadcasters are no longer the traditional producers of video material to be broadcasted in just one format and medium but in a range of formats and mediums as the so-called IP-based content delivery network.

A first effort was done in VIDION to re-use information that has to be produced in other departments of a broadcaster operator when DVB is introduced. Classification of **Series** and **Programmes** is based on the descriptors defined by the Selection Information Tables (SIT) in [ETSI 1998] (see Section 3.6) allowing an automatic upload of these fields by parsing the income stream of a live feed input.

5.4.4 Content identification and referencing

The DS developed to VIDION provides mechanisms to deal with the management of different instances of the same content. In the simplest case, content will be created and recorded only once. However more complex scenarios were considered as, in most of the cases, more than one instance of the same content will be produced. Two possible situations can occur: 1) content has exactly the same structure and duration; 2) content is similar but may have some differences in duration.

The first case can occur when more than one copy is produced and recorded in a different support, possibly with different qualities or different coding schemes. This is a typical case in a broadcast archive operation: a viewing copy usually co-exists together with one or more full quality instances of the content provided in different supports. All these copies are regarded as different instances of the same content and a master copy is defined (the best quality and less used instance) so that new copies can be reproduced from the original.

A different situation happens when two or more slightly different versions of the same programme are produced. In these cases, the duration of the streams is usually different and although the main reality documented in the content is the same (e.g. a sports event or a concert), the content is different due to the production of a shorter version of the same programme, the use of a different camera, an editing operation, etc.

In the first case, all the versions share the same time line and the same indexing between the different copies. A segment, once identified in one of the copies, can be automatically mapped onto the equivalent in any other instance. All the version of the content are automatically related based on a similar mechanism as the one provided by MPEG-7 *MediaIdentification* descriptor and the SMPTE UMID *Material number*. Each of the copies is uniquely identified using mechanisms similar to the ones provided by MPEG-7 *Mediaprofile* DS and SMPTE UMID *Instance number* (see Section 3.7). The master version is easily identified by **Instance Number:= 0**.

In the second described situation – different durations – the time line of each of the copies cannot be mapped one to one and the identification of a specific segment in each copy is not trivial. From the archive perspective, due to the difference in the content, each of these versions is considered a different programme. However, track of the relation between all the related pieces is provided through a reference to an original or master segment.

5.4.5 AudioVisual Object Storage

A segment of a given content (e.g. a **Programme**) might have been stored sequentially in just one support or can be broken in different tapes or files. It can also be broken in several pieces by the introduction of inserts (e.g. commercials) which don't belong to the content. So that indexing of the segment is not affected by this interlacing of external components or by the split of the same content by different supports, the concept of 'Section' was created to provide a logical continuity of the segment as illustrated in Figure 5.6.

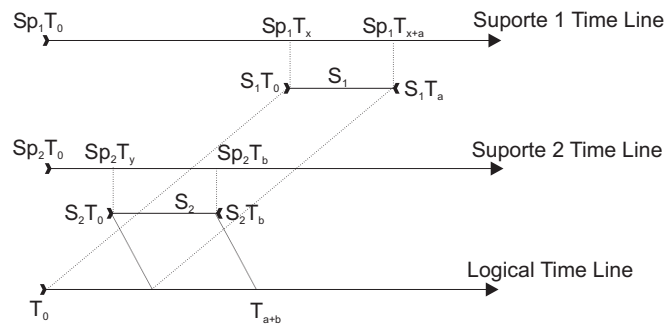


Figure 5.6: VIDION section and support

In the example, an **AudioVisualObject** of T_{a+b} duration is made of 2 *Sections* — S_1 and S_2 . S_1 has a duration of a and is positioned at time T_x of Support Sp_1 and S_2 has a duration of b and is positioned at time T_y of Support Sp_2 . A logical timeline is constructed to produce the final unbroken content.

5.5 RTP Network Requirements

The system uses TCP/IP as the support protocol for metadata and video transfer, allowing system deploying on top of generic IT networks. The advent of networking infrastructure capable of gigabit speeds further facilitates the service of storage over the network allowing architectures as the one developed. This is, as stated in Chapter 4, expected to reduce the need of using specific network technologies like Fibre Channel or SDTI inside television facilities.

The implementation of VIDION in RTP required the interconnection of different buildings as the department responsible for the archives (the content provider) and the News Department (the client) are located in different towns.

Figure 5.7 presents the main elements of the solution installed and tested in RTP. The global network infrastructure is based on two LANs interconnected through ATM Public Network with a bandwidth negotiated with the service provider. The testbed in RTP was based in a 16Mbps VP.

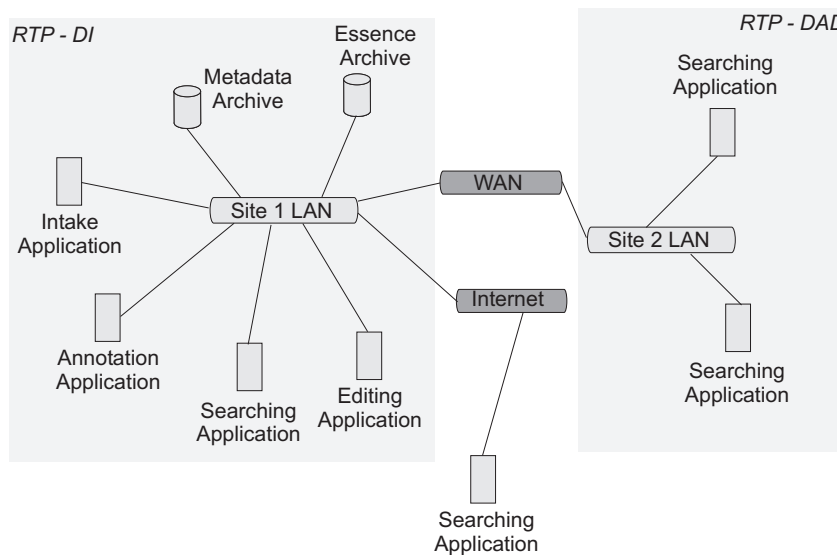


Figure 5.7: VIDION network infrastructure in RTP

Having a limited bandwidth and sharing the same VP for data and video transfer, can lead to situations where QoS is not guaranteed as video transfer can be affected by bursts of data caused by metadata transfer. To solve this problem, the present implementation defines two different IP networks (one for video and another for metadata) and the separation of traffic from each of the networks through 2 different PVC (Permanent Virtual Circuit). The testbed at RTP uses a 12Mbps for synchronous traffic. This solution doesn't guarantee, however, QoS for each individual video channel but only an aggregated QoS for all the video links by assuring that a burst on data transfer doesn't affect the total bandwidth allocated for video.

5.6 VIDION deployment and test

From the hardware point of view, the VIDION system consists of several linux servers running the services (e.g. authentication, database management and studio services) and windows workstations running the applications. The On-Line archive was implemented

through a hardware-based RAID on Red Hat linux. The Near-On-Line archive was implemented using a StorageTek ACL 9730 robotic library having a drive for DLT 7000 tapes that enables transfer rates of about 5Mbps. The total amount of storage approaches 1 Terabyte. The intake system used Betacam and VHS VTRs. Networking was implemented through ATM (LE-155 of Fore Systems) and Ethernet Switches.

From the software point of view, it consists of device drivers for controlling boards and equipment, client and server applications and databases.

Beside exhaustive testing by the developing team, the prototype was deployed and tested in a real world environment following EBU guidelines presented in Section 1.5: a project group was set up for that purpose consisting of documentalists, researchers and journalists. The following steps were implemented:

1. *Personnel Training* — a selected number of documentalists participated in a one day tutorial and hands-on session followed by individual training. Tutorials were provided and a helpdesk was setup.
2. *System Population* — different types of material were digitised and made available for annotation. Trained personnel followed the complete annotation process and made content available for in-house and Internet search and browse.
3. *System Testing* — researchers and journalists went through some internal training sessions and worked as testers of the *Browsing* and *Editing* applications.
4. *System Tuning* — based on the feedback provided by users, each of the applications was fine-tuned and enhanced graphical interfaces were designed.

Based on these experiments and also on a smaller testbed installed in BBC R&D some conclusions can be drawn regarding the solution developed:

1. the initial ideas concerning the use of IT technologies and the main concepts defined proved to be correct;
2. the *Annotation* and *Browsing* Applications were deemed as essential working instruments, providing innovative working methods and adding exceptional functionalities to the archive. Having the documentalist place of work reduced to a general purpose PC was found as one of the greatest functionalities provided: the old working methods required a panoply of devices on the desk, ranging from a VTR and a monitor to a set of remote control devices, a stopwatch, etc;

3. less annotation errors were noticed and extra metadata was made available for searching;
4. access to content was made much easier and more accurate;
5. the *Editing Application* was regarded as not crucial as the functionalities provided by professional solutions were greater but, mainly, because journalists were not used to perform some pre-editing functions. This situations might be modified if additional training is provided to journalists and a new workflow is implemented;
6. Internet access was not received enthusiastically. Once again, business level decision might reverse this situation: not only could it become an instrument for new B2B or B2C scenarios but also for a new public service provided by broadcasters that might be financed by the Government.

Setp 2 and 3 of the EBU guidelines were not implemented due to internal decisions of RTP. Although these tests are not expected to bring new important feedback concerning the main architectural decisions and functionalities developed, they could be important for testing system scalability.

5.7 VIDION in the context of a B2B scenario

The effort on harmonisation of metadata within Broadcasters has proved elusive as organisations have different internal needs. VIDION provides mechanisms for managing complex media assets through the definition of a DS and a set of Ds, by providing tools that make the access to content easy and by providing means for the introduction of new functionalities.

In a scenario of B2B, the introduction of export modules that enable the conversion between different DS is required. This task is as more difficult as the differences in concepts are great.

The segment decomposition of the content presented in this chapter is in line with some of the proposals presented in Chapter 3. Although some of them don't define how a segment should be divided in subsegments (as MPEG-7) or the number of pre-defined levels is different from the one provided in this scheme, mapping between this proposal and other is possible either by mapping directly entities (DS) or descriptors. Table 5.6 presents the mapping between VIDION concepts and P_Meta concepts while Table 5.7

illustrates the mapping between VIDION Ds and two of the defined P_Meta Sets.

Table 5.6: VIDION and P_Meta concepts mapping

P_Meta	VIDION
<i>Segmentation</i>	
Brand	Asset
Programme Group	Series
Programme	Programme
Item Group	Item
Item	Scene
<i>Composition</i>	
AudioComponent	Media Object
VideoComponent	Media Object
DataComponent	Media Object

Table 5.7: VIDION and P_Meta descriptors mapping

P_Meta	VIDION
1 S38:PROGRAMME_IDENTIFICATION	
2 [	
3 S32:IDENTIFIER [	
4 A105:IDENTIFIER_NUMBER	Prg.Document.Number
5]	
6 S49:PROGRAMME_TITLE_HISTORY [	
7 A110:PROGRAMME_TITLE	Prg.Series.Title
8 A107:PROGRAMME_SUB_TITLE	Prg.Sub.Title
9 A114:PROGRAMME_EPISODE_TITLE	Prg.Title
10]	
11 A104:PROGRAMME_EPISODE_COUNT	Prg.Number
12 S11:CONTRIBUTION [	
13 A124:ROLE_TYPE_CODE	Prg.Staff.Category.Code
14 A125:ROLE_TYPE_NAME	Prg.Staff.Category.Name
15 A124:ROLE_NAME	Prg.Actor.Character
16 S12:PERSON_DETAILS [	
17 A89:PERSON_LAST_NAME	Prg.Staff.Name
18 A88:PERSON_FIRST_NAME	Prg.Staff.Name
19 A89:PERSON_LAST_NAME	Prg.Actor.Name
20 A88:PERSON_FIRST_NAME	Prg.Actor.Name
21]	
22]	
23 A152:PRODUCTION_END_DATE	Prg.Production.Data
24]	

continued on next page

Table 5.7: VIDION and P_Meta descriptors mapping (*cont.*)

P_Meta	VIDION
25 S39:PROGRAMME_DESCRIPTION	
26 [	
27 A29:EOV_DURATION	Prg.Duration
28 A109:PROGRAMME_SYNOPSIS_DESCRIPTION	Prg.Synopsis
29 A103:COLOUR_CODE	Prg.Copy.Video_Cmpt.Colour_Code
30 A176:SUBTITLE_FLAG	If(Prg.Copy.Video_Cmpt. Subtitle_Lang.Code)
31 S18:LANGUAGE_HISTORY [	
32 A65:LANGUAGE_CODE	Prg.Copy.Audio_Cmpt.Lang.Code
33 A66:LANGUAGE_NAME	Prg.Copy.Audio_Cmpt.Lang.Name
34 A65:LANGUAGE_CODE	Prg.Copy.Video_Cmpt. Subtitle_Lang.Code
35 A66:LANGUAGE_NAME	Prg.Copy.Video_Cmpt. Subtitle_Lang.Name
36 A408:LANGUAGE_USAGE_DESCRIPTION	Prg.Translation
37]	
38 S10:LOCATION [	
39 A214:LOCATION_ACTION_NAME	Prg.Item.Place_of_Action
40 A67:LOCATION_CAPTURE_NAME	Prg.Place_of_Production
41 A207:LOCATION_SETTING_NAME	Prg.Item.Place_of_Production
42]	
43 S17:KEYWORD [	
44 A68:EDITORIAL_CONTENT_CODE	Prg.Classification
45 A56:INDEX_KEYWORD_NAME	Prg.Item.Descriptor
46 A56:INDEX_KEYWORD_NAME	Prg.Item.Scene.Descriptor
47]	
48]	

5.8 Concluding remarks

This chapter presented the overall architecture of a system intended to provide an efficient tool to manage a broadcaster archive. It was developed within the research context of a Portuguese project but following and contributing to the main activities going on in this area.

The prototype, deployed in a real world environment, constitutes the case study of this thesis and the background for further proposals presented in the next chapters.

The first conclusion that can be drawn from the work presented in this chapter is that the use of IT based solutions in broadcaster environments was a correct decision. The system proved to fulfill the requirements of the users in a real environment defined for step 1 of the EBU recommendation concerning the deployment of MAM systems in large

broadcast organisations.

Another conclusion is that harmonisation of all the metadata schemes presented in Chapter 3 is almost impossible. Mapping between concepts, DS and Ds is the proposed solution that is exemplified through the mapping of P_Meta concepts and VIDION.

The use of a middleware that hides implementation details and location of services and streams has proved to be a good solution for the management of a complex system as the one presented. The introduction of external services and the management of services and stream location is made easier by the use of this approach. Although the middleware solutions used in this implementation were based on the CORBA and RMI technologies, the use of other solutions based on Web Services would be possible.

The final conclusion, and one of the most important, is that lots of effort is being put in different projects and initiatives for the definition of metadata models, but equivalent effort is not being taken on the definition of methods that will allow the management of system resources. Effective deployment of such a system in a real environment requires, however, the development of those management platforms that enable an efficient system use for all the players involved in the TV archive — from the creative people to the technical and administrative manager. Those resource management aspects have not been, up to now, the main concern of researchers and system developers but are a critical issue for the exploitation of this kind of systems.

Chapter 6

Resource Management Approaches

Having as background the proposed model and prototype presented in Chapter 5, this chapter highlights the problems of management a complex MAM in a scenario of real world deployment. It presents the current approaches being developed by the R&D community and describes a proposal that is expected to facilitate the integration of heterogenous media applications and products.

6.1 Introduction

The deployment of a MAM system to support the management and exploitation of audio-visual archives, as the one presented in Chapter 5, rises a number of problems that have not been dealt with by the research community.

Associating metadata to content, using standard IT networks and workstations instead of the expensive equipment usually required in a traditional broadcasting environment, defining an architecture composed by a set of different archives, with different accessibility and quality, including Internet based access, as well as defining a data model for the metadata, was the first step towards the development of a prototype.

Lots of effort has been put in different projects and initiatives for the definition of metadata models: ISO-MPEG7 for generic multimedia information description, EBU-P/META and SMPTE in broadcaster environments and Dublin Core for a larger range of domains as presented in Chapter 3.

Some effort has also been put on the definition of requirements and generic models for MAM systems in broadcasting as stated in [EBU/SMPTE 1998] and [EBU 2001a].

Equivalent effort is not being put on the definition of methods that will allow the management of system resources¹.

However, the value of the archive content is derived mainly from the level of re-use and, although metadata and storage architectures have been considered to be important areas of research that would enable this re-use, effective deployment of such a system in a real environment requires further developments: a management platforms that enables an efficient system usage by all the players involved in the TV archive — from the creative people to the technical and administrative manager [Viana and Alves 2000]. Those resource management aspects, that shall enable the management of all the different system devices and usage alternatives, have not been, up to now, the main concern of researchers and system developers in the area of the MAM system but are a critical issue for the operation of this kind of systems as a huge amount of very valuable material comes into these archives every year.

The work on solving the problem of resource management has been mainly driven by the networking community with solutions provided by IETF and ISO through the definition of protocols (SNMP — Simple Network Management Protocol and CMIS/CMIP — Common Management Information Service/Protocol) and information models intended to enable network monitoring and management. Some solutions have also been deployed by the broadcasting community in order to solve specific problems of device management.

Each of these approaches deals with problems of very restricted areas of application and specific aspects of some application areas are not covered. These multiple approximations result in 1) different mechanisms for information interchange; 2) different languages for information specification and 3) different schemas for information specification. All these differences result in compatibility problems that make an integrated management approach impossible, as access to resources requires using different models.

More recently, some activity that started driven by the networking community, but that is currently trying to address generic management problems, has been happening within the industry driven Distributed Management Task Force (DMTF).

The problem of storage resource management has also recently been addressed through a set of standards released by IEEE. This was enforced by the growing number of storage architectures and related protocols in the IT world (Section 4.3).

¹In the context of this thesis, the word ‘Resources’ is used to refer to all the components and equipment that make up the system. It should not be confused with the, also commonly used in the multimedia community, alternative meaning of ‘Content’.

The next sections present an overview of the different approaches related to management of resources in areas associated with media asset management systems.

6.2 Control Protocols Characteristics

Control, management and monitoring protocols within the broadcasting industry have been evolving separately in different operation areas resulting in a wide range of solutions each bearing a specific set of functionalities that are the result of diverse premises and prerequisites [ASSET 2002].

Although all these three operations (control, management and monitoring) are usually associated, they have different purposes: 1) Control protocols enable the trigger of audio, video or metadata processes on a device or component; 2) Management protocols enable the configuration of a device or component by setting one or more parameters that affect their operation and 3) Monitoring protocols refer to the assessment of the state of the device such as the free space in a storage device or the traffic in a network link.

The comparison of command and control protocols requires the analysis of different operation aspects namely the context of communication, timeline characteristics and communication relationship.

Devices to be controlled may provide just a single channel or multiple inputs/outputs. In the latter case, the identification of the operation context is required during the course of the control process to determine which input/output signal or audio/video file the control commands refer to. As devices require some time to respond to, e.g., the association of stored essence to input/output channels, these processes generally occur before control commands that trigger real-time operations. Protocols that require or provide mechanisms for identifying the input/output channel are said to possess a context of communication. Contextless protocols are those used to control linear devices like VTRs where the context is defined automatically by the device itself (one single channel for the playout of video signal).

For the control of real-time interfaces, such as SDI, the delay imposed by a command is a critical factor. The timeline characteristics of a protocol provide mechanisms for defining the delay of a control command by enabling the specification of the time of execution as an additional parameter of the command. The implementation of these deferred operations requires the definition of mechanisms that enable the initiation of actions coupled

to the device's system time as well as the background processing and queuing of commands. Although most of the protocols implement stop and wait mechanisms, requiring that a command is processed before a new one can be issued, background operations can be available for commands that demand long processing time. This functionality enables the controller to issue further commands before the return values of the background commands have arrived. Queuing of commands enables the sequential execution of several commands that are intermediately stored in the controlled device. Deferred and background functionalities are crucial when using TCP/IP as the underlaying protocol for the control of broadcast equipment, due to the restricted real-time capabilities of the protocol.

The existing protocols are based on the Master/Slave or Master/Agent models. The later provides some functionalities that increase the utilisation of the communication channel and of the controlling device as the agent is capable of sending messages to the manager even if they have not been requested. The device being controlled is then capable of monitoring itself and generating messages whether in the slave configuration the device is not capable of initiating any communication process by itself requiring the manager to constantly query the state of the device.

6.3 Device Specific Command and Control Protocols

6.3.1 VTR Control

Sony provides a protocol for the control of VTRs that can be used by different manufacturers. It is based on a master/slave relationship between the controlling device and the VTR and uses RS422 as the communications channel. It doesn't allow deferred commands execution.

Although it was designed mainly for the control of VTRs, the protocol also provides functionalities for monitoring and managing devices — status information can be requested and settings of the device can be modified.

The protocol doesn't incorporate any commands for context definition as it is implicitly determined. This makes the protocol not suitable for controlling other similar devices — e.g controlling a video server would require a context.

6.3.2 Media Object Server Protocol

The Media Object Server Communications Protocol is intended to allow the integration of Newsroom Computer Systems (NCS) and Media Object Servers (MOS) through the use of a common communication protocol [MOS 2006a]. The NCS entity enables the creation, modification and deletion of editorial information. Media items are associated with this information and playlists are created. The MOS — any device capable of storing Media Objects (Video Servers, Audio Servers, Still Stores, and Character Generators) — is in charge of ingesting, editing, storing and deleting media objects and their associated metadata. The term ‘MOS’ is used to name the protocol and also as a generic name for the device which is controlled.

The protocol allows both devices to initiate the communication through two bidirectional TCP/IP sockets and to exchange XML messages of the following type²:

1. *Descriptive Data for Media Objects*: allows the transfer of metadata from the MOS device — as objects are created, modified, or deleted in the MOS — to the NCS so that it becomes aware of the MOS’s contents and can perform searches and manipulate the data that it has received from the MOS. The exchange of information is done through **Media Object Metadata** messages initiated by the MOS through an independent bidirectional socket connection.
2. *Playlist Exchange*: allows the transfer of playlists from the NCS to the MOS so that the NCS can control the sequence that media objects are presented by the MOS. These commands, initiated by the NCS and labelled in the protocol as **Running Orders** type of messages, are exchanged through a bidirectional socket connection.
3. *Status Exchange*: allows the MOS to inform the NCS of the status of specific clips or of the MOS system in general. The NCS can also notify the MOS of the status of specific playlist items or running orders.

The XML messages enable the precise definition of the communication context by specifying both the controlling device and the device being controlled as illustrated in Table 6.1 for a **Running Order** message that allows basic control of a media object server via simple commands such as **READY**, **EXECUTE**, **PAUSE**, **STOP** and **SIGNAL**.

²The use of Web Services for the exchange of messages is been defined and is available in its draft version [MOS 2006b]

Table 6.1: Running Order Control DTD and message

1	// DTD
2	<!ELEMENT roCtrl (roID, storyID, itemID, command,mosExternalMetadata*)>
3	<!ELEMENT command (READY EXECUTE PAUSE STOP SIGNAL)>
4	
5	// Message
6	<mos>
7	<mosID>aircache.newscenter.com</mosID>
8	<ncsID>ncs.newscenter.com</ncsID>
9	<roCtrl>
10	<roID>3dedde9jd</roID>
11	<storyID>A3fds3d</storyID>
12	<itemID>30848</itemID>
13	<command>EXECUTE</command>
14	</roCtrl>
15	</mos>

The MOS protocol provides no support for real-time commands but defines deferred timeline commands to be executed by a media object server at a previously defined time. The behaviour of the system to commands transferred without parameters defining the execution time is not specified by the MOS protocol.

Although the protocol was designed to coordinate the communication between a central NCS (the master) and a set of o MOS servers (the slaves), it enables both devices to initiate the message exchange.

The MOS protocol has a narrow scope as it was designed to address a single need: the interaction of a NCS and a set of MOS devices within a newsroom. Direct interaction between MOS servers, media exchange and complex metadata schemas are out of the scope of the protocols.

6.3.3 Network Device Control Protocol

The Network Device Control Protocol (NDCP) is an industry disclosed solution that aims at providing a network-based control of audio-video devices. It was designed as a successor of the Video Disk Control Protocol (VDCP), which aims at controlling video disk systems, and of the Video Archive Control Protocol (VACP), which is restricted to manage the content of archives, and to move contents between archives. NDCCP aims at providing a larger scope solution and to be able to control most of the broadcast

equipment used in transmission: from a one-channel character generator to a video server with multiple channels allowing then to control the recording and playback of material through audio/video or data ports, to manage the content of a device and to transfer media assets between devices.

NDCP uses TCP/IP as the underlaying protocol to obtain a network-independent solution for connectivity via local or wide area networks.

The context of the communication is defined by the allocation of different handles, an address that identifies one virtual device, as the protocol defines the concept of Elementary Broadcast Device Objects (EBDOs) and enables the aggregation of multiple of these virtual objects to represent a physical device. Each of the EBDOs represents an elementary functionality, such as the storage or the A/V ports of the device being controlled, enabling the real-time creation of virtual devices just by combining specific functionalities available within physical devices.

Real-time and deferred commands are provided by a special EBDO.

The protocol uses XML encoded messages in a master-slave configuration and supports both real-time and deferred commands structure to facilitate the remote control of devices in distributed television facilities.

6.4 Digital Storage Media Command and Control

Digital Storage Media Command and Control (DSM-CC) [ISO/IEC 1998; Balabanian et al. 1996], Part 6 of MPEG-2, is an ISO/IEC standard developed to provide the control functions and operations specific to managing MPEG-1 and MPEG-2 bitstreams. These protocols may be used to support applications in both stand-alone and heterogeneous network environments. In the DSM-CC model, a stream is sourced by a Server and delivered to a Client. Both the Server and the Client are considered to be Users of the DSM-CC network.

Clients are, in general, devices such as set top boxes that consume multi-media content. Servers are entities that provide multi-media content and services. A Server may be a distributed system, contain multiple computing platforms and some specialised functionally such as video pumps to provide video on demand services. A Server thus may have multiple transport connection points to the Network.

Two types of messages are defines: 1) User-to-Network (U-N) and 2) User-To-User (U-U). A U-U information flow is used between a client and a server. The U-N information

flows between the network and the client or the server and their purpose is to control sessions and network resources.

In a typical DSM-CC scenario, a client (e.g., a set-top box) would upon start-up, use the U-N config message set to configure itself for the network it is attached to. U-N configuration can be initiated by the user (messages `UNConfigRequest`, `UNConfigConfirm`) or by the network (`UNConfigIndication`, `UNConfigResponse`), or as a consequence of a user listening to a well-known broadcast channel (`UNConfigIndication`). After a U-N config message sequence, the client becomes aware of network-specific parameters. The client also receives a default service location.

The DSM-CC U-U part provides a generic set of multimedia user-to-user interfaces that implement modular building blocks to be used by a wide range of multimedia applications (from movies on demand, to teleshopping, to games and distance learning).

The U-U stream interface provides VCR-like control to the client. The file interface allows a client to read and write files stored on a server, while the directory interface provides navigational facilities. Example of messages are *Stream Pause*, *Stream Resume*, *Stream Jump* and *Stream Play*.

A typical scenario for using DSM-CC is a video-on-demand service. At startup, a client (e.g. a set-top box) would initiate U-N Config to configure itself using information stored in the network. A U-N Session Setup is then used to set up a session between the client and server through the network. Then, based on context information received by the client in the U-U Session attach message, connections are set up for download. Download is invoked to retrieve the appropriate client software. Using the U-U directory functions, a navigator application would provide a menu of options to the user. Once a selection is made, U-U download may again be used for the client to acquire necessary code corresponding to the menu choice. For a video selection, U-N `AddResource` messages are used to set up new connections for the video and audio streams. U-U Stream Manipulation functions are then available to the user.

6.5 Simple Network Management Protocol

The Simple Network Management Protocol (SNMP) [Case et al. 1990] was developed and standardised by IETF and is mainly supported and implemented by the IT industry.

It is based on the agent/manager model: 1) the *SNMP Agent* resides in the managed device, has local knowledge of management information and translates that information

into a form compatible with SNMP; 2) the *SNMP Manager* monitors and controls managed devices in a network. Operation is mostly polling based (the agent responds to management requests) and a special type of messages was defined — the **trap** messages — to enable the agent to notify the management application of significant events, such as errors on the device, a change of the state in a variable, etc.

The protocol provides no mechanisms for real-time or deferred operation as commands are processed after arrival.

SNMP is compatible with a wide range of transport protocols and, besides defining the overall architecture and the messages/protocol that enable the interaction between the manager and the agent, it is part of a larger framework that specifies the variables in the collection of objects being managed — the *Management Information Base* (MIB) [McCloghrie and Rose 1991] — and the language and rules used for describing those objects — the *Structure of Management Information* (SMI) [McCloghrie et al. 1999].

The existing MIBs are addressing, mainly, the following aspects:

1. *Network Management*: the MIBs defined for this purpose provide information concerning communication protocols, mainly statistical information about traffic.
2. *System Management*: the goal of this set of MIBs is to provide information on devices rather than on the communication protocols.
3. *Distributed Management*: this group of MIBs is designed in order to enable a single, stand-alone, remote entity to gather information from all the network acting as a monitoring device.
4. *Administrative Management*: the objective is to provide mechanisms that enable the secure control/configuration of devices through authentication and access control.

Although SNMP was mainly driven by the network community and the initial targets were TCP/IP routers and hosts, many manufacturers of broadcast devices have defined private MIBs and provide SNMP mechanisms for device management within television facilities [Baldock et al. 2000].

The SNMP information model is very simple, complex data-types and methods can only be modeled indirectly and the only operations allowed on SNMP objects are read and write: **Get**, **GetNext** and **GetBulk** messages enable, respectively, the single-instanced

objects and table objects access and **Set** enables setting a variable. This simple variable-based rather than object-oriented approach may result in extra-complexity when trying to model complex real entities. Furthermore, although operations like **GetBulk** and **Trap** were intended to extend the framework functionalities, the practical implementation of these operations has some problems: 1) the use of UDP and the possibility of IP fragmentation and consequently the increase of packet loss probability reduces the effectiveness of bulk transfers as a response to a **GetBulk** should fit in a single packet; 2) the use of unreliable traps in the first implementations of SNMP agents makes the use, by management stations, of this functionality quite unusual being most of the operations polling-based.

The main strength of SNMP is its simplicity what contributed to a widely adoption of this management framework. However, this advantage has also been acting as its main drawback due to the difficulty of performing some management operations such as load/restore configurations in a consistent way, activate a new configuration at a specific time, and roll back a configuration. This has led to its application mostly in monitoring and performance management but hardly never for configuration management.

6.6 Storage Resource Management

Until recently, storage devices have been managed and controlled by a single data movement application installed with them. The shift to networked architectures, where storage devices and hosts are connected to networks interconnected by routers and switches, brought the possibility for each host to access each storage device increasing the complexity of the system. One of the problems brought by this new scenario is the lack of a standard that isolates the applications from the storage hardware, implying adaptation of devices to existing applications or rebuilt of applications to support new hardware. The other problem is the management complexity of such a system where a number of records concerning the media, access conflicts, transfer operations, etc, require tools for storage management.

Storage community is mainly concerned with tape libraries, as tapes still represent a fundamental part of data centers. A central and standard mechanism to view and manage all these storage resources and that is able to report management information currently available only to the application that owns the device, would enhance flexibility and scalability provided by storage networks.

With the implementation of large storage systems, some requirements are foreseen:

- i. centralized resource management that provides secure sharing of tapes and other storage equipment among multiple heterogeneous applications;
- ii. platform and operating system independence to enable multiple vendor integration;
- iii. application independency to provide media management functionalities for a wide range of applications.

Besides these general requirements, tape management could be improved if a list of functionalities were provided:

1. automatic tape recycling;
2. tape retirement based on the age of the tape and on the number of times it has been mounted;
3. automatic movement of tapes from near-online to off-line.

Some activities, in different standardisation bodies, have been happening [Viana and Alves 2002; Deicke and Mueller 2003] trying to address these problems. The next sections present an overview of some of the most important initiatives in the storage area.

6.6.1 IEEE Management Model

The IEEE Media Management System (MMS) [IEEE 2000a] defines a distributed and platform independent architecture for managing removable media. It defines the architecture, data model, protocols and interfaces to handle devices such as disks and tapes, using robotic and manual methods. Currently, five standards were release:

1. Media Management Systems (MMS) Architecture [IEEE 2000a]
2. Session Security, Authentication, Initialization Protocol (SSAIP) [IEEE 2000b]
3. Media Management Protocol (MMP) [IEEE 2000c]
4. Drive Management Protocol (DMP) [IEEE 2000d]
5. Library Management Protocol (LMP) [IEEE 2000e]

Some other aspects as inter MMS communication and information interchange [IEEE 2002] to provide load balancing and fail over capabilities are still under development.

The Media Manager Interchange Protocol (MMIP) is intended to facilitate the transfer of content between different MMS by transferring the metadata associated with that content. The separate MMS might be spread over different sites of the same organisation or in different organisations.

The architecture defined is intended to overcome problems like robot or drive sharing, application complexity and manufacturer dependency. It defines a three-tiered model where the client applications access the media devices through a central point that shares and controls all the system (Figure 6.1) allowing to take the complexity of media management out of applications and introduce it into a framework.

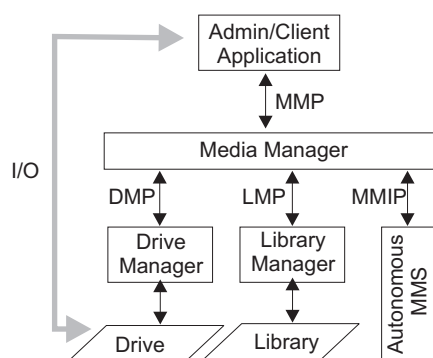


Figure 6.1: IEEE MMS Architecture and Protocols

The *Media Manager* acts as a central repository of metadata describing the storage resources and provides all the mechanisms to control and coordinate the allocation and use of media, libraries and drives among multiple client applications. Hardware is connected to the core of the system through managers (the library or drive managers) that provide abstract interfaces that hide hardware detail. Detailed information of the content and capabilities of the hardware connected to the system is kept in the manager that controls the equipment. This hardware virtualisation enables the support of different manufacturers and models.

The data model describing components of the storage system (cartridges, drives, libraries, applications, etc) provides a list of allowed objects in the MMS, their attributes, names, data types and semantics. The 40 defined objects are organised in 8 clusters to provide an intuitive understand of the system. For each object, a list of attributes is defined in the form of `OBJECTNAME.AttributeName`. Tables 6.2 and 6.3 illustrate this model for the `LIBRARY` and `LM` object.

Table 6.2: Excerpt of the **Library** object attributes

Attribute	Description	
LIBRARY.LibraryName	Type:	Characteristics, Key
	Data Type:	String
	Description:	The name of the library
	Allowed Values:	Any
	Default:	None
	Depends On:	None
	Depended On By:	CARTRIDGE, DRIVE, LM, LIBRARYDRIVE, MOUNTPHYSICAL
LIBRARY.LibraryDisabled	Type:	Control
	Data Type:	Enumerated
	Description:	An administrative control used to enable/suspend/disable use of this library.
	Allowed Values:	<i>true, false, temporary</i>
	Default:	<i>false</i>
	Depends On:	None
	Depended On By:	None
LIBRARY.LMName	Type:	Control
	Data Type:	String
	Description:	The instance name of the LMP currently controlling this library.
	Allowed Values:	One of the entries in LM.LMName
	Default:	None
	Depends On:	LM.LMName
	Depended On By:	None

Relationships between different objects is provided by the **Depends On** and **Depends On By** attributes that identify the objects that shall be created first. In the example provided by Tables 6.2 and 6.3 the dependence between the **LM.LibraryName** and **LIBRARY.LibraryName** is made clear and requires the following steps whenever a **LIBRARY** is added to the MMS:

1. create a **LIBRARY** object with an empty string value for **LMName** and with **LibraryOnline** set to *false*;
2. create an **LM** object and define one **LMName**;
3. **LIBRARY.LMName** may be given a non-empty value;

Table 6.3: Excerpt of the LM object attributes

Attribute	Description	
LM.LibraryName	Type:	Characteristics, Key
	Data Type:	String
	Allowed Values:	One of the entries in <code>LIBRARY.LibraryName</code>
	Default:	None
	Depends On:	<code>LIBRARY.LibraryName</code>
	Depended On By:	None
LM.LMName	Type:	Characteristics, Key
	Data Type:	String
	Description:	The name of an LM for the Library specified in <code>LM.LibraryName</code>
	Allowed Values:	Any
	Default:	None
	Depends On:	None
LM.LMMessageLevel	Depended On By:	<code>BAY, LIBRARY, SLOT, SLOTCONFIG</code>
	Type:	Control
	Data Type:	Enumerate
	Description:	The message level for logging
	Allowed Values:	'emergency', 'alert', 'critical', 'error', 'warning', 'notice', 'information', 'debug', 'developer'
	Default:	'error'
	Depends On:	None
	Depended On By:	None

4. set `LIBRARY.LibraryOnline` to *true*.

MMS protocols are text-oriented and have asynchronous command-response style, using TCP/IP as the underlying protocol. These protocols enable the manipulation of objects defined in the data model that characterise the physical and logical components of an MMS. Commands are divided in *data model-oriented* or *operation-oriented* depending on the nature of the actions that are involved when executing the command: the first do not imply the direct involvement of the Drive and Library Managers while the later provide access to media. Examples of commands that act on the data model are **create**, **delete**, **privilege**, **rename**, **show**. Commands such as **eject**, **mount**, **move**, **shutdown** not only affect the objects instantiated in the MMS but also execute a set o jobs related to the architecture.

2. *Common Models* — information models that capture notions common to particular management domains but independent of a particular technology or implementation. The common domains include *Systems*, *Applications*, *Devices*, *Users*, *Networks*, *Policies* and *Databases*;
3. *Extension Models* that represent technology-specific extensions of the Common Models. These models are specific to environments, such as operating systems, or to vendors.

All the models are based on the *CIM Meta Schema* that defines the terms used to express the model and its usage and semantics. The definition of this *Meta Schema* follows an OO approach and uses UML to define the basic constructions of CIM, including **Schemas**, **Classes**, **Properties**, **Methods**, **Indications** and **Associations** (Figure 6.2). A textual representation of the metamodel and of the different models is also provided by the standard using the MOF syntax that, besides serving as a specification of the managed objects, can also be processed using a compiler.

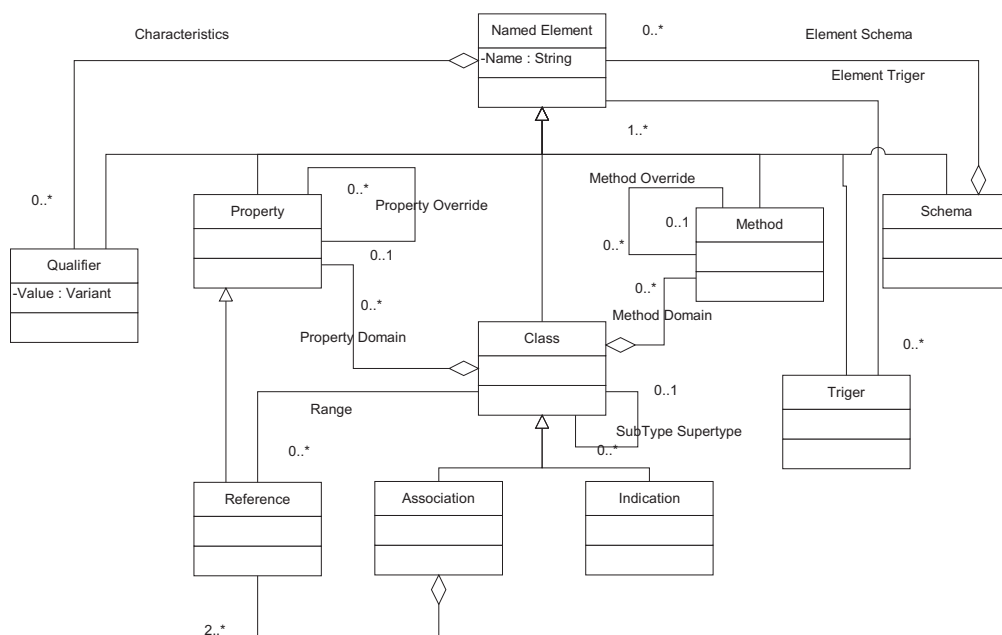


Figure 6.2: CIM Meta Schema v2.2

An excerpt of the MOF description of the `CIM_StorageLibrary` is exemplified in Table 6.7 where the class declaration (name and inheritance), the definition of the `Capabilities` attribute and of the `EnableRobotics` method are clearly identified.

Table 6.7: `CIM.StorageLibrary` class expressed in MOF (excerpt)

```

1 //Class StorageLibrary
2   [Version ("2.6.0"), Description (
3     "A StorageLibrary is a collection of"
4     "ManagedSystemElements..."]
5   class CIM.StorageLibrary:CIM.System {
6     [Description (
7       "Capabilities of the StorageLibrary."),
8       ValueMap {"0", "1", "2", "3", "4"},
9       Values {"Unknown", "Other", "Automatic Cleaning",
10        "Manual Operation", "Front Panel Lockable"} ]
11     uint16 Capabilities[];
12     [Description (
13       "Requests that the Library robotics be enabled"
14       "or disabled.The return value should be 0 if"
15       "successfully executed,1 if the request is not"
16       "supported and some other value if an error"
17       "occurred.") ]
18     uint32 EnableRobotics(
19       [IN]
20       boolean Enable);
21   };

```

Management applications use a request-response message exchange protocol containing XML-encoded CIM operations. The use of HTTP as the message exchange bus is possible through the extension of the protocol request methods, error codes and headers. `CIM Message Requests` are encapsulated within the HTTP `POST` or `M-POST` methods and `CIM Message Responses` are carried in the corresponding HTTP `Response` message to the `M-POST` or `POST` request.

The operation requests are invocations of one or more methods classified as 1) *Intrinsic* — defined outside of the schema — or 2) *Extrinsic* — defined as methods on a CIM class in some schema. These two method calls are differentiated by the use of the XML elements `<IMETHODCALL>` and `<METHODCALL>`. Intrinsic methods can act on metadata (Classes) — `GetClass`, `CreateClass`, `DeleteClass`, `ModifyClass`, `EnumerateClassNames`, etc

— , data (Instances) — `GetInstance`, `DeleteInstance`, `CreateInstance`, `ModifyInstance`, `GetProperty`, `SetProperty`, `EnumerateInstances`, `EnumerateInstanceNames`, etc — , or can be used to enumerate CIM objects that are associated to a particular object — `Associators`, `AssociatorNames`, etc.

Table 6.8 illustrates a request operation for the class `CIM_VideoBIOSElement` encapsulated in a HTTP message. The request uses HTTP extension headers as defined in RFC 2774 [Leach and Lawrence 2000] and includes an XML entity body which defines the operation according to the CIM DTD defined by DMTF. Table 6.9 presents the HTTP response to that request, indicating success of the `GetClass` requested operation. The complete definition of the returned `<CLASS>` element has not been shown to make the example more clear.

Table 6.8: HTTP request the class `CIM_VideoBIOSElement` [DMTF 2007c]

```

1  M-POST /cimom HTTP/1.1
2  HOST: http://www.myhost.com/
3  Content-Type:application/xml;charset="utf-8"
4  Content-Length: xxxx
5  Man: http://www.dmtf.org/cim/mapping/http/v1.0 ; ns=73
6  73-CIMOperation: MethodCall
7  73-CIMMethod: GetClass
8  73-CIMObject: root/cimv2
9  <?xml version="1.0" encoding="utf-8" ?>
10 <CIM CIMVERSION="2.0" DTDVERSION="2.0">
11   <MESSAGE ID="87872" PROTOCOLVERSION="1.0">
12     <SIMPLEREQ>
13       <IMETHODCALL NAME="GetClass">
14         <LOCALNAMESPACEPATH>
15           <NAMESPACE NAME="root"/>
16           <NAMESPACE NAME="cimv2"/>
17         </LOCALNAMESPACEPATH>
18         <IPARAMVALUE NAME="ClassName">
19           <CLASSNAME NAME="CIM_VideoBIOSElement"/>
20         </IPARAMVALUE>
21         <IPARAMVALUE NAME="LocalOnly">
22           <VALUE>FALSE</VALUE>
23         </IPARAMVALUE>
24       </IMETHODCALL>
25     </SIMPLEREQ>
26   </MESSAGE>
27 </CIM>

```

Table 6.9: HTTP response indicating success for the `GetClass` requested [DMTF 2007c]

1	HTTP/1.1 200 OK
2	Content-Type: application/xml; charset="utf-8"
3	Content-Length:xxxx
4	Ext:
5	Cache-Control: no-cache
6	Man:http://www.dmtf.org/cim/mapping/http/v1.0 ; ns=73
7	73-CIMOperation: MethodResponse
8	<?xml version="1.0" encoding="utf-8" ?>
9	<CIM CIMVERSION="2.0" DTDVERSION="2.0">
10	<MESSAGE ID="87872" PROTOCOLVERSION="1.0">
11	<SIMPLERSP>
12	<IMETHODRESPONSE NAME="GetClass">
13	<IRETURNVALUE>
14	<CLASS NAME="CIM_VideoBIOSElement" SUPERCLASS="CIM_SoftwareElement">
15	...
16	</CLASS>
17	</IRETURNVALUE>
18	</IMETHODRESPONSE>
19	</SIMPLERSP>
20	</MESSAGE>
21	</CIM>

CIM is implementation independent, allowing the interchange of management data in multi-platform distributed environments. Mapping to other management models, as the IETF network management environment SNMP-MIB, is already provided.

6.7.1 Mapping IEEE MMS and CIM models

The CIM approach is intended to be implementation independent and to allow the interchange of management data in multi-platform distributed environments. The integration of other management models requires, however, the translation of information specified in the other domains to a common model defined by CIM.

Collaboration with other organisations like IETF (for SNMP network management) and IEEE (for disk and tape management) is expected to assure a large compatibility between solutions. Storage Networking Industry Association (SNIA) (an association of a large number of industries) whose purpose is to ensure that storage networks become efficient, complete and trusted solutions by promoting SAN interoperability and management, defined a Shared Storage Model [SNIA 2001], which describes a set of possible

Table 6.10: HTTP response indicating error for the `GetClass` requested

```

1  HTTP/1.1 200 OK
2  Content-Type: application/xml;charset="utf-8"
3  Content-Length:xxxx
4  Ext:
5  Cache-Control: no-cache
6  Man:http://www.dmtf.org/cim/mapping/http/v1.0 ; ns=73
7  73-CIMOperation: MethodResponse
8  <?xml version="1.0" encoding="utf-8" ?>
9  <CIM CIMVERSION="2.0" DTDVERSION="2.0">
10   <MESSAGE ID="87872" PROTOCOLVERSION="1.0">
11     <SIMPLERSP>
12       <IMETHODRESPONSE NAME="GetClass">
13         <ERROR CODE="5" DESCRIPTION="The specified Class does not exist"/>
14       </IMETHODRESPONSE>
15     </SIMPLERSP>
16   </MESSAGE>
17 </CIM>

```

storage network architectures and defines a common vocabulary to be used when comparing and designing systems. Concerning technology, SNIA is adopting some of the DMTF standards in order to create an open API for discovering, monitoring and managing devices on a SAN. Mapping IEEE MMS disk and tape management into a CIM compliant model might be a first step towards this integration.

Mapping different models into a CIM common model can be done through a set of different approaches [Strassner 1999]:

1. *Content Mapping* — a mapping is defined that maps non-CIM data directly into CIM data. Meta-models constructs are used as guidelines, but do not directly affect the mapping;
2. *Meta-model construct-based Mapping*— the CIM metamodel constructs are used to describe the meta-model constructs of the non-CIM model. This enables non-CIM data to be expressed indirectly as CIM data. This technique relies on being able to express data and object structures and relationships as CIM constructs;
3. *Meta-model equivalent Mapping* — The meta-model constructs of the non-CIM model are translated to CIM meta-model constructs. This enables the non-CIM data to be translated into CIM data.

Figure 6.3 presents an excerpt of the CIM object model for a storage library and how the IEEE MMS services can be mapped under `CIM.Service` class. Mapping between IEEE object attributes into CIM properties is exemplified in Table 6.11 for the `Library` and `Library` objects.

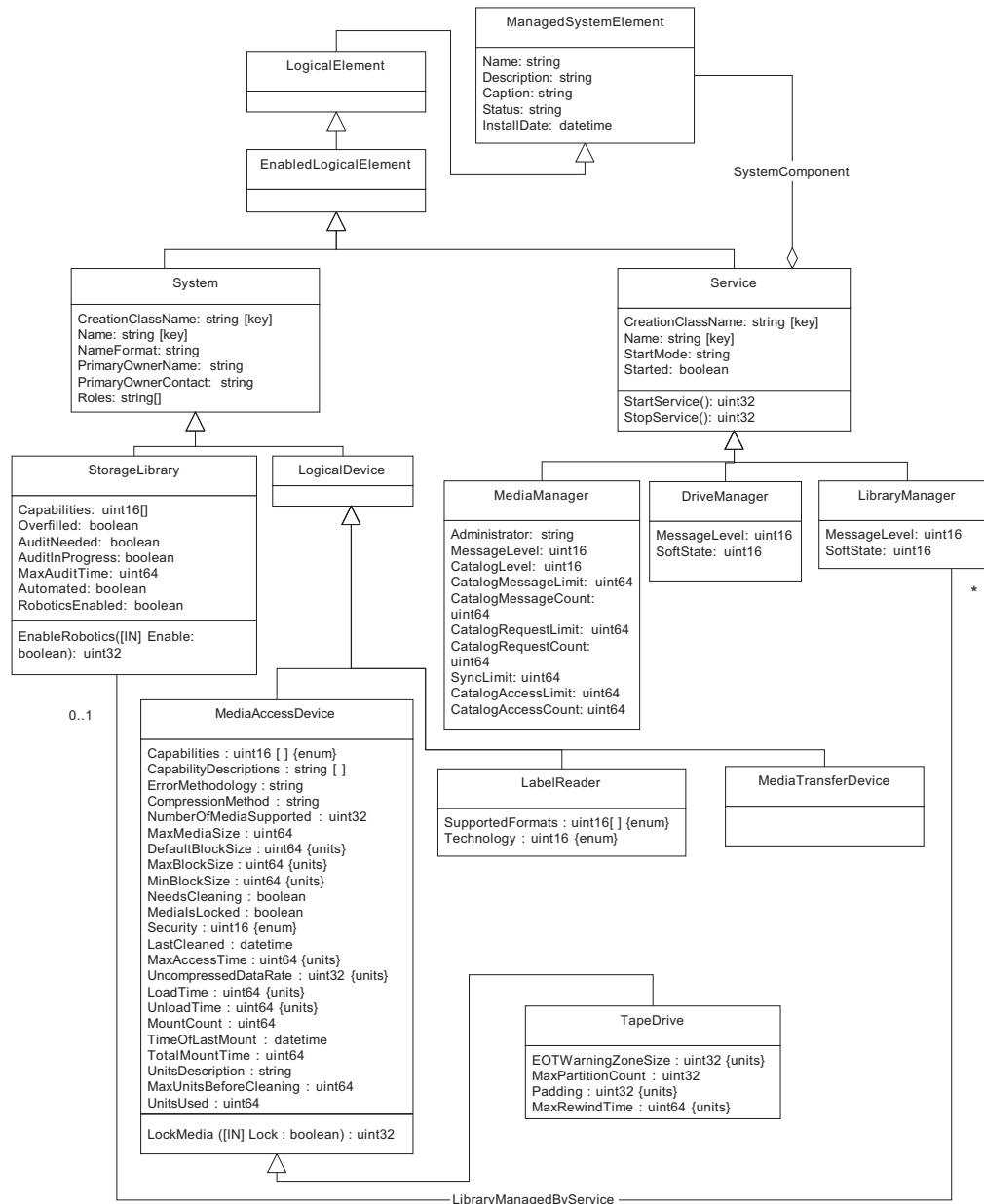


Figure 6.3: CIM object model for Storage Libraries (excerpt)

Table 6.11: Mapping IEEE Library object into CIM (excerpt)

IEEE attributes	CIM property
LIBRARY.LibraryName	System.Name
LIBRARY.LibraryOnline	StorageLibrary.RoboticsEnabled
LIBRARY.LibraryDisabled	ManagedSystemElement.Status (inherited to StorageLibrary)
LIBRARY.LMName	LibraryManagedByService.CurrentManager
LM.LibraryName	Defined by an instance of the LibraryManagedByService association
LM.LMName	Service.Name
LM.LMMessageLevel	LibraryManager.MessageLevel
LM.LMStateSoft	LibraryManager.SoftState
IEEE LIBRARY is mapped in CIM.StorageLibrary, an existing subclass of CIM.System	
IEEE LM is a new CIM.LibraryManager subclass of CIM.Service	

6.8 A Broadcast Oriented Management Architecture

The approaches presented in the previous sections result in a multiplicity of protocols and languages with different complexity, extensibility and applicability as presented in Table 6.12.

The diversity of models may result in inter-operability problems that make difficult the homogenous management of heterogenous resources. Furthermore, some of the solutions, although having been disclosed, were developed by a sole institution resulting in architectures that were mainly driven by specific products requirements. The lack of formality on defining a meta-model from which different models are derived makes, in most of the cases, the extensibility of the solution rather difficult.

The use of XML as the language to describe manageable objects and managing actions has started to be adopted by a set of solutions. This approach presents some advantages over previous ones [Straus and Klie 2003; Choi et al. 2002; Pavlou et al. 2004; Klie and Straus 2004; Schonwalter et al. 2003; Menten 2004]: 1) XML Schema can be used to define the structure of management information in flexible way; 2) Widely deployed protocols such as HTTP can be used to transfer management data described in XML; 3) Standardised XML related technologies can be used to access and manipulate management data (DOM [W3C 2000] and SAX [Brownell 2002] APIs), to generate HTML reports (XSLT

Table 6.12: Management models comparison

Model	Protocol	Language	Schema	Scope	Type	Complexity	Extensability
IETF	SNMP	SMI	MIB	Network/ Systems	Open	-	-
WBEM	HTTP	UML/ MOF/ XML	CIM	General	Open	+	+
MMS	MMP/ DMP/ LMP	EBNF	List of objects and their attributes	Storage (Removable De- vices)	Open	+	-
VTR	RS422	-	-	VTR Control	Industry released	-	-
MOS	MOS	XML	List of objects and their attributes	NCS	Industry released	-	-
NDCP	NDCP	XML	List of EBDOs and their attributes	Audio-Video devices	Industry released	-	-

[W3C 2003b]) and to address objects within management data (XPath expressions [W3C 2003a]). Figure 6.4 illustrates how XML technologies and associated tools relate to each other.

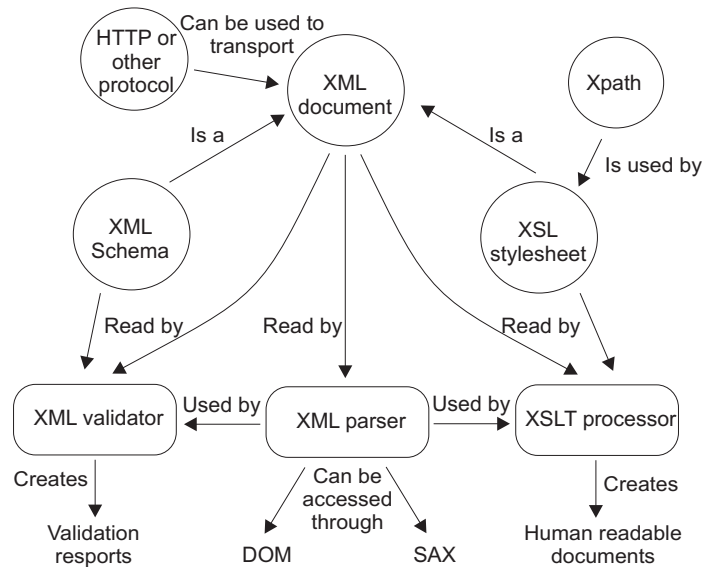


Figure 6.4: XML related technologies and tools [Straus and Klie 2003]

These current efforts of applying XML to system management are accomplished in, however, limited management areas, the technology is mainly used to describe objects and specific protocols are used, making it difficult to apply these solution directly to other areas such as the one that is being studied in this thesis.

The WBEM is a first attempt towards the integration of different domains. However, although it proposes a protocol and a data model that aim to be independent of the application fields, it has some drawbacks as it doesn't provide solutions for direct application in a broadcasting environment. Its main problems are 1) The complexity of the data model; 2) The lack of rules and mechanisms for translation between data models; 3) The lack of domain dependent requirements like real-time operations and 4) The lack of interoperability with other metadata schemes.

The solution presented in this section exploits a number of approaches to solve some of these problems. This architecture re-uses some of the concepts defined in the previous proposals and defines a set of interfaces and protocols for the integration of media

applications and products in broadcaster environments. By defining a framework that incorporates agents (for compliant devices) and proxies (for legacy products) that are able to interpret command and control XML based messages and a set of services that aggregate some common functions, this solution is a step ahead from the previous proposals.

6.8.1 The ASSET Architecture

The ASSET architecture [Viana et al. 2003; Rodrigues et al. 2003; Body et al. 2003; Cordeiro et al. 2003, 2004] is based upon a software Framework — the ASSET Framework — composed by a set of standard interfaces and protocols for applications and products working together in an integrated environment. Once applications are connected to the Framework, they can communicate with any other application. Products from different manufacturers can be natively connected to the ASSET Framework (using an *ASSET Agent*) or through a software adaptor (the *ASSET Proxy*) enabling their control and management by any ASSET compliant application connected to the Framework.

The Framework allows the easy integration of Media services (such as content ingestion, content indexing, content transcoding, content retrieving, etc.) as well as Media products (such as Video Servers, Archive Servers, VTRs, etc.). The proposed solution is based on open standards and emerging technologies and defines the concept of an Asset Middleware that wraps the standard software layered architecture into a software middleware, which proposes:

1. The abstraction of broadcast software and hardware devices as logical resources;
2. Generic, openly defined and simple interfaces to control devices and data distribution;
3. A set of services that automate some of the most common functions in a broadcasting environment.

Applications communicate with the framework using the ASSET Public API, which allows them 1) to communicate with any other application; 2) to access the public services provided by the framework; 3) to use additional functionalities implemented by third party integrators as aggregated services. Products from different manufacturers are integrated in the ASSET framework either natively (using an ASSET agent) or via an ASSET proxy. They are controlled and managed through the Media ASSET Bus API, based on XML service schema definitions. This API ensures an easy and seamless integration of devices

and products in the framework. An ASSET Private API is defined to access core services of the framework (*Common Services*) that enable the workability of this integrated environment. This API is only used internally in order to guarantee the overall system integrity.

The main components of this architecture are depicted in Figure 6.5.

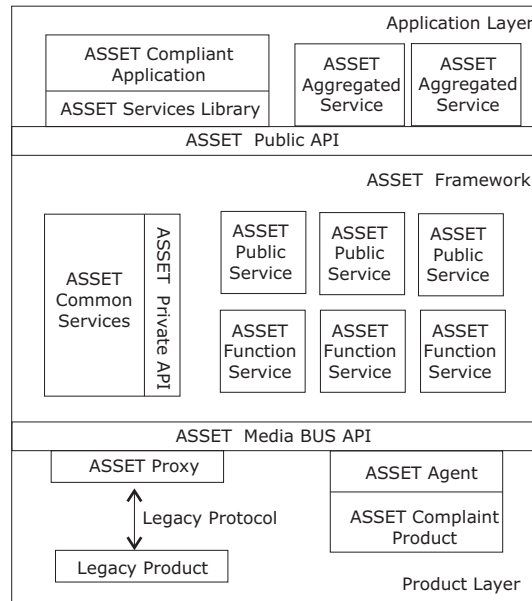


Figure 6.5: ASSET Architecture

The ASSET Components

The core of the ASSET Framework consists of three main components that provide different layers of services enabling the design of new applications on top of available services:

1. *The ASSET Common Services* provide implementation of key infrastructure requirements such as security, logging, notification, resource management, etc. This allows a uniform and single implementation of these services throughout the solution;
2. *The ASSET Function Services* provide an abstraction of functionalities (encoder, recorder, player, etc.) to other ASSET services. They hide the specificities of the different interconnected products (e.g. for a public service, a VTR output and a Video Server output are considered as two system-wide logical output ports).

By using resource management services, they are also used to check function availability and to ensure consistency (e.g. ensure that an Audio/Video input port has not been already locked by another ASSET service);

3. *The ASSET Public Services* expose the mandatory services of the ASSET framework to the applications through the ASSET Public API. These services provide a minimum set of multimedia functionality, sufficiently rich and extensible not to limit the system efficiency. They ensure the consistency and integrity of the system by handling the internal logic (e.g. access right, resource allocation, etc.) required for each operation.

At the Application layer, three components are introduced:

1. *The ASSET Compliant Applications* are the top level ASSET software components. They use the ASSET Public API to access services provided by the ASSET Framework and, optionally, by ASSET aggregated services. In order to simplify application implementation, they shall not call directly functions provided by ASSET agents or proxies.
2. *The ASSET Services Library* is a software component that makes an application compliant to the ASSET framework and gives it access to the ASSET public services.
3. *The ASSET Aggregated Services* implement additional logic on top of public services (or even other aggregated services). They register in the framework as new services available for ASSET compliant applications (e.g. complex workflows may be specified as aggregated services and then, be available for other connected applications or aggregated services). An example of an ASSET aggregated service can be an ingest service that is built on top of a recorder function, a transcoder function and the ASSET notification service (to notify applications connected to the Framework that a new essence has been acquired).

A product is a manageable hardware or software component implementing one or several functions. For example, most of the Video Server products implement a Recorder function (managing the Audio/Video input ports), a Player function (handling the Audio/Video output ports) and a Storage function (managing the storage repository where essence is recorded to or played from). Making a product compatible with the ASSET

framework is achieved using one of the following techniques:

1. *An ASSET Compliant Product* is a product that is managed by the framework through a built-in ASSET Agent. This agent understands ASSET protocols enabling the direct control of the implemented functions (e.g. play, record, rewind, etc)
2. *A Legacy Product* is a product that has no built-in ASSET agent. The ASSET framework can, nevertheless, managed such a product through an external software module called an ASSET Proxy. This proxy translates ASSET protocol and commands to the product proprietary command and control protocol.

6.8.2 ASSET message exchange format and transport

The ASSET modules uses a XML based message exchange format defined for providing a common way for adapter implementations to describe their function and parameters (Table 6.13).

Table 6.13: ASSET generic message structure

1	<asset-message type="type of message">
2	<asset-header>
3	<!-- Generic header information -->
4	</asset-header>
5	<asset-data>
6	<!-- The message data comes here -->
7	</asset-data>
8	</asset-message>

The message header contains global information common to the system. For example, a session ID could be maintained to keep track of consecutive messages. This ID would be generated by the adapter stub instance. The same ID would be transmitted for all subsequent "processCommand" messages.

Different message types were available to allow, for example, registering, initialising and processing a command: 1) `registerAdapter` and `registerAdapterResponse`; 2) `lookupAdapter` and `lookupAdapterResponse`; 3) `initializeAdapter` and `initializeResponse`; 4) `processCommand`, `processCommandAcknowledgement` and `processCommandResponse`; 5) `statusQuery` and `statusQueryResponse`.

For sending a ‘Play’ command to a VTR connected to the framework, a XML message of the type `processCommand` is sent, via the transport abstraction layer, to the proxy of this VTR (e.g. VTR1). The VTR proxy converts this ‘Play’ command to the device specific protocol (eg. Sony protocol) and sends it over the physical link (eg. RS422) connecting the proxy to the VTR. The XML message used to implement this operation is illustrated in Table 6.14. The body part of the message identifies the device, the action to be performed and the parameters to be used. The operation is agnostic to the specificities of the product that implements this core functionality. Additional services provided by the framework enable checking the permissions for this operation request, creating a transaction identifier and locking the logical port so that it is made unavailable to other requests.

Table 6.14: ASSET `processCommand` message

```

1  <asset-message type="processCommand">
2    <asset-header>
3      <asset-header-block>
4        <header name="session-id" value="8CE983D392"/>
5      </asset-header-block>
6      <asset-header-block>
7        <header name="security" value="user1/xxxx"/>
8      </asset-header-block>
9    </asset-header>
10   <asset-data>
11     <asset:COMMAND asset:DEVICE="VTR1">
12       <asset:ACTION asset:name="PLAY">
13         <asset:PARAMETER asset:name="speed" value="2"/>
14       </asset:ACTION>
15     </asset:COMMAND>
16   </asset-data>
17 </asset-message>

```

The message structure is similar to the one defined for the CIM’s XML operation so that it can be easily translated to an extrinsic CIM message as presented in Table 6.15.

Sending and receiving XML messages is enabled by the implementation of a *Transport Abstraction Layer* that hides implementation details: different transport mechanisms such as JMS, HTTP or SOAP can be used as a common interface is provided. The main benefits of this abstraction layer are: 1) the client need not know the semantics for sending a message over a transport medium as he gets a consistent interface for sending and receiving messages irrespective of the transport used; 2) any change in the transport for

Table 6.15: Translation of the ASSET `processCommand` message to an extrinsic CIM message

```

1  <CIM CIMVERSION="2.0" DTDVERSION="2.0">
2    <MESSAGE ID="87872" PROTOCOLVERSION="1.0">
2      <SIMPLEREQ>
2        <METHODCALL NAME="Play">
2          <LOCALINSTANCEPATH>
2            <LOCALNAMESPACEPATH>
2              <NAMESPACE NAME="root"/>
2              <NAMESPACE NAME="myNamespace"/>
2            </LOCALNAMESPACEPATH>
2            <INSTANCENAME CLASSNAME="VTR">
2              <KEYBINDING NAME="VTR1"><KEYVALUE>VTR1</KEYVALUE></KEYBINDING>
2            </INSTANCENAME>
2          </LOCALINSTANCEPATH>
2          <PARAMVALUE NAME="speed"><VALUE>2</VALUE></PARAMVALUE>
2        </METHODCALL>
2      </SIMPLEREQ>
2    </MESSAGE>
1  </CIM>

```

communicating with a certain component does not affect the client.

6.9 Concluding Remarks

Although some work has been developed by the R&D community towards the definition of standard management protocols, the solutions currently available lack the functionalities required for the effective integration of media applications and products in Broadcaster environments.

The work developed within the ASSET project (*Architectural Solutions for Services Enhancing digital Television*) and presented in this chapter is a first step towards the development of an integrated asset management environment by providing the basis for the communication between media applications (eg. content ingest, content indexing, content transcoding, content distribution, etc.) and media products (video servers, archive servers, browsing servers, etc.). The proposed architecture defines a set of APIs and services that enable abstracting from the working model and make the integration of different systems independent from the device manufacturer, programming language and

underlying middleware platform.

Nevertheless all the proposals discussed in this chapter address low level problems and are not aware of one of the main problems that a broadcaster archive manager faces: the implementation of high level decisions that require information from multiple sources. The next chapter presents an architecture proposal for the integrated management of audiovisual archives that is supposed to help solve a number of the problems currently faced in the broadcasting world: the integration of information from multiple sources and a framework to enable a business driven management of their assets.

Chapter 7

Business-Driven Broadcast Archives Management

Managing a large scale MAM, having as support heterogeneous networks, aggregating many manageable items and hosting valuable content possibly described using different DS, requires the development of efficient management platforms. Chapter 6 introduced a solution that is expected to facilitate the integration of applications and equipments from different vendors. However, by dealing with low level operational aspects, it doesn't provide an integrated high-level view of the archive nor the mechanisms for managing the asset based on high level decision criterions. This chapter introduces the concept of Business-Driven Management and illustrates its application towards the effective management of the valuable assets available in the most important broadcasters.

7.1 Introduction

The integration, in a Broadcaster facility, of software applications and equipment from different manufacturers is a complex task as interoperability is not provided both at the protocol level and description models for content or devices. This can be regarded as an ontological problem as the different software entities involved in a set of crucial processes, that should share and interchange information, structure their knowledge in different ways.

The previous chapters presented an extended overview of the different problems concerning interoperability and management in media archive departments. The lack of a solution is both due to the complexity of the problem and to the large number of scientific

areas that have to be addressed. It is clear that most of the solutions proposed concerning media asset management solutions were driven by isolated communities that lack the integrated vision of the problem.

The following conclusions may be generated from the previous chapters:

1. An integrated vision about material holdings, problems associated with its access and preservation status information is missing or is concentrated within a short number of persons that almost manually manage the archive's content;
2. Solutions for metadata models that enable content description emerged from a large number of departments and activity areas don't provide a solution that might enable the exploitation of the valuable asset that some broadcast companies own. These solutions were mainly developed by technicians who missed the overall view of the archive and of its components (from content itself to the underlying technologies like networking and archiving devices);
3. Media area networks architecture and products suffered from parallel developments coming either from the IT world or the broadcasting industry. This situation led to the development of a set of different technologies and approaches that are either quite application oriented and expensive or that don't easily integrate with legacy systems;
4. Management protocols and models were initially driven by the networking community, first with the introduction of SNMP and CMIS and later through the evolution towards integrated models like CIM. This work was, much later, followed by the storage community that either developed its own proprietary solutions like MOS and MMS or tried to adopt existing solutions from the networking community (like the SNIA effort on adopting CIM).

The described approaches and works answer the question of media asset management only partially. There is no continuous approach to derive demands from a business process of an archive owner and to map these demands on an adequate architecture to integrate management applications along these processes. Rethinking management from a business perspective, whether this be in an operational, tactical or strategic context is obviously needed. The development of separate solutions that are not alert to the complexity of the problem and are not aware of the solutions being brought up from different activity

areas have slow down the emergence of an integrated vision and solution for media asset management tools in broadcasting.

This chapter presents an approach that it expected to contribute towards a solution that will enable new paradigms for the management of broadcasting archives. This approach is based on a new concept presented in literature as *Business Driven IT Management* (BDIM) as it creates a new layer that is not aware of the underlying implementation and is expected to provide a simple interface from a business manager point of view.

7.2 Business Driven IT Management

The main objective of the *Business Driven IT Management* approach, a new concept introduced in [Aib et al. 2005; Machiraju et al. 2005], is to drive the management of IT resources and services from the business point of view, looking beyond IT services to the business context where the services are used. The main focus of BDIM is then on the business: IT must help on the business to achieve its goals, contributing to its results in a measurable way. Results can be of a financial nature (revenue, cost, etc) or different, like asset utilization, or even reflect intangibles such as impact on the company's image. It involves a new culture, tools and decision-making processes that should aim to help business [Sauvé et al. 2006; Moura et al. 2007] by allowing IT-related decisions to be taken from a business perspective.

In the BDIM context, goals are set to align IT to business and to make IT-related decisions like optimal capacity planning, optimal IT resource allocation, prioritizing incidents or changes, that will impact business processes and results. Data gathering tools or modules may have to be integrated to collect information for subsequent control and adjustment. BDIM tools are expected to automate decision support in settings of interest to manufacturers, providers, users and managers of complex systems and services.

This approach is based on the definition of business metrics like revenue, profit, costs, time from order to fulfillment, frequency of new product launches, average time for collection, etc, that measure beneficial results (e.g. revenue) or adverse results (e.g. loss).

As stated in [Sauvé et al. 2006], quantifying BDIM metrics is a complex task that requires not only knowledge about the IT infrastructure but, primarily, models that capture the complex relationships between IT performance, IT services and business processes using the underlying infrastructure. A significant research effort is still required to mature and to consolidate this approach for IT management.

In the context of broadcast archives, business-driven management should be based on the assumption that the value of a media archive is derived mainly from its level of re-use. Metadata and storage architectures, as well as low level management models, have been considered important areas of research that would enable content re-use. However, they usually cover restricted areas of application, interoperability and aggregated views as well as knowledge of the system are not provided.

In this chapter we argue that a new concept, based on the BDIM approach, should be considered for the deployment of effective management platforms in broadcast archives. The definition of a layered model that isolates IT and content direct management from a top level business layer is expected to allow the combination of multiple techniques and to provide a model solution. The first step towards the implementation of the proposed architecture is the definition of a *Metadata Integration Framework* that will aggregate information from different domains and help the manager have a partial view of such a complex system.

7.3 Business-Driven Management Using a Metadata Integration Framework

As discussed in Chapters 3 and 6, a number of metadata models have been proposed in order to allow the implementation of important tasks in media access and system management. However, due to the complexity of the problem, most approaches pick up a particular problem. The initiatives described in the previous chapters cover aspects directly related with device management (disk, tape libraries, network devices, etc) and define management metadata without relating the system with the application area. On the other side of the line, Broadcasters' archivists have been mainly interested on the definition of a metadata schema that enables the process of searching and locating items in their huge assets.

These two working areas are not dealing with the problem of aggregating descriptive metadata with management metadata to allow an integrated view of the archive and to avoid data inconsistency in the two different layers.

7.3.1 Problem Description by Example

The need for information integration from different domains, when dealing with aspects of BDIM in a broadcaster archive, can be better illustrated by the presentation of some examples that provide simple cases of such synchronization requirements:

Example 1 Suppose a programme that is archived in two different files (for example, part 1 and part 2 of a news magazine) as defined for the VIDION solution in Section 5.4.5. For the client applications (searching and editing workstations), due to metadata introduced in the descriptive archive by the annotation workstation, the program is seen as just one stream. For the management application, they are however different files, possibly with different number of accesses. Using inactivity as the criterium for moving material to a secondary storage device (e.g. a tape library) in a hierarchical storage management approach, would introduce an unwanted difference between the two files of the same programme.

Example 2 Due to the large amount of material with recycling needs, the prioritisation of tape transcription due to preservation needs depends on tape characteristics available in the Storage Resource Management (SRM) system, including number of times it was mounted, read and written, but also on descriptive information classifying a program. This last information is only available from content description metadata;

Example 3 Technology obsolescence may also dictate the need for content migration. The hardware available for tape reading, information obtained in the SRM, may be crucial for defining the prioritisation of recycling. Once again, the final decision shall be based on the genre of the programmes affected or in other content characteristics as defined in Section 2.5.3;

Example 4 When different quality versions of the same content are available, the network capacity and availability information coming from SRM metadata may determine which version should be sent to a user. Content description information associating different versions to a single programme item is then needed.

Example 5 Stream migration between the different type of archives defined in the proposed architecture (Section 5.2.2) depends on the disk capacity

available from the SRM system but also on description information aggregating video, audio and key frames files available from content metadata. File access logs available from the SRM system may also provide essential information concerning important material that has been rarely used and should be highlighted.

Analysing the different examples presented, two conclusions can be immediately highlighted: 1) the integration of the two metadata domains will provide extra information and 2) there is the need for another metadata plane that shall define a set of rules that enable business or high-level management decisions:

1. Migration between archives is not only dependent on disk capacity available on a server but also on the percentage that a manager wants to have free;
2. Prioritisation of re-cycling has to be done not only based on tape preservation aspects but on a policy defining the importance of the items contained;
3. Renewing the rights of use of a given programme depends on the costs and on the current or expected value of that content;
4. Available bandwidth may have to be reserved based on the editorial constraints.

Given the size of a typical broadcasting archive, its historical and economic value and its preservation problems, these examples clearly demonstrate that some crucial tasks of a management application are not easily implemented using the available metadata information as 1) it is too complex for the purpose of management, 2) no integration of the different models is provided, 3) some business-driven management related metadata is missing and, finally, 4) it is difficult to have specialised personnel with knowledge in all the areas.

The work presented as part of this dissertation proposes the integration of those three metadata planes and is expected to enable a step ahead on Media Asset Management solutions in a broadcaster environment [Viana and Alves 2002]. The definition of a domain ontology that captures and provides a formalisation of the problem and enables the description of different aspects that affect management is presented.

7.4 Management Ontology

Content description schemas as the ones described in Chapter 3 and the one proposed in this thesis and presented in Chapter 5 are quite complex as their main purpose is not only to provide generic description of the content but also to enable the temporal or spatial segmentation of each stream.

For the purpose of effective asset management based on a business-driven perspective, a lighter model is better suited. This new model shall highlight the most important topics that may result in extra revenue due to a better utilisation of the asset or may reduce the negative results (e.g. lost of content due to material degradation). A large number of the detailed descriptions provided by the former models do not provide extra functionalities and make the development of management applications more difficult. In this section, a domain ontology is proposed.

[Grüninger and Fox 1996] proposes a generic, domain independent, methodology for the creation of ontologies. This method envisages the implementation of four steps:

1. *Identify purpose and scope*: Clarify why the ontology is being built and what its intended users are;
2. *Building the ontology*: The identification of the purpose and scope of the ontology, at least in general terms, serves to provide a reasonable well-defined target to build the ontology. This process entails three sub-phases:
 - i. *Ontology capture*: This phase includes the identification of the key concepts and relationships in the domain of interest. This conceptualisation can be represented in a semi-formal representation.
 - ii. *Ontology coding*: Provides the explicit representation, in some formal language, of the conceptualisation captured in the previous stage. This process involves: 1) committing to the basic terms that will be used to specify the ontology (class, entity, relation); 2) choosing a representation language and 3) writing the code.
 - iii. *Integrating existing ontologies*: During either or both the capture and the coding steps it is possible and even desirable to reuse [all or part of] existing ontologies. In general, this is a quite difficult problem.

3. Evaluation: Make the technical judgment of the ontologies, their associated software environment, and documentation with respect to a frame of reference. This frame of reference may be requirements specifications, competency questions, and/or the real world.
4. Documentation: Good documentation is the basis of knowledge sharing and ontology reuse. Documentation includes description of the concepts and of all the important assumptions.

The first step of this algorithm has already been performed and clearly illustrated in the previous sections and by the examples provided. The next sections present the proposed domain ontology developed by following the steps numbered as 2.i), 2.ii) and 2.iii). The last two phases of the process of ontology creation are presented later in this document: *Evaluation* was achieved through the population of the ontology and *Documentation* is available as Appendix A.

7.4.1 Conceptualisation

Despite the variety in metadata models, all the specific proposals share common concepts and properties when describing audiovisual documents or devices. For instance, the concepts of *Genre* or some *Production* and *Broadcast* properties (*Target Audience*, *Broadcast Date*, *Live* or *Pre-recorded Broadcast*) are always needed either for cataloguing and indexing or to parameterize an algorithm whose goal is to extract automatically some features from the signal.

Another aspect that is present in most of the description schemas is the *Credits List*, that is, the people and their roles in the programme. Technical activities, such as *Direction*, *Production*, *Pos-production* (Special Effects, Captions, etc), or people actually participating in the programme as *Actors*, *News Readers* or as *Interviewed Guests* can be used as key information concerning the management of the archive.

Example 3 in Section 7.3.1 presents one of the problems that the most important archives face: media obsolescence. Migration to a new support requires the manager (either a person or a software application) to be aware of the *media format* of a given audiovisual object. Besides the genre or the actors involved in the programme, prioritisation on migration may be determined by a set of factors where the programme award list may be important.

The next step is to introduce relations between the different entities in order to structure the knowledge and enable reasoning. Taking into account the examples, some relations can be elicited: 1) relations between the audiovisual objects and people (**hasProducer**, **hasParticipant**), 2) relations between the audiovisual object and the broadcast properties (**hasAudience**, **isLive**, **wasBroadcastedAtTime**), 3) relations between the audiovisual object and technical features (**hasFormat**, **hasRights**) and 4) relations with external ontologies that identify e.g. places.

The detailed conceptualisation of this ontology has been done through the use of *Protégé 2000* [Gennari et al. 2003], one of the editors available in the market. This tool provides the mechanisms for an easier visualisation and organisation of the different concepts and their relation.

The main concern on building this ontology was to integrate, in a unique view, information from the different domains giving the manager an upper view of the main aspects that might affect management: the **AudioVisualObject** and the **ManagedElement** are the two main classes of this ontology and enable, respectively, the description of content and of the systems to be managed based on some criterion to be defined. Auxiliary classes (**Person**, **Property**) were added to enable additional information to be inferred from the ontology. Extending the ontology can be done by adding new classes (e.g. **Place**) to the current version. Figure 7.1 presents a graphical view of the first two levels of this ontology that will be detailed in the next sections. This representation, although not giving too much detail on the properties of each element or on associations between them, enables the manager to have a fast glance through the main classes proposed.

The AudioVisualObject

This ontology distinguishes audiovisual content based on two concepts: their processing status (either a final **Programme** or **Rushes** coming directly from the camera without editing) and their level of importance (e.g. Keyframes, audio tracks, etc are considered to be **OtherMedias** that might be associated to a **Programme** through an **has-associatedMedia** association but that are not the main object of management).

The **AudioVisualObject** is defined as a superclass that aggregates these three concepts and has a set of generic properties (**title**, **synopsis**, etc) that are inherited by the subclasses. The characterisation of the object **Programme** requires the definition of a set of other properties (**has-genre**, **has-team**, **has-targetAudience**, etc) that provide extra

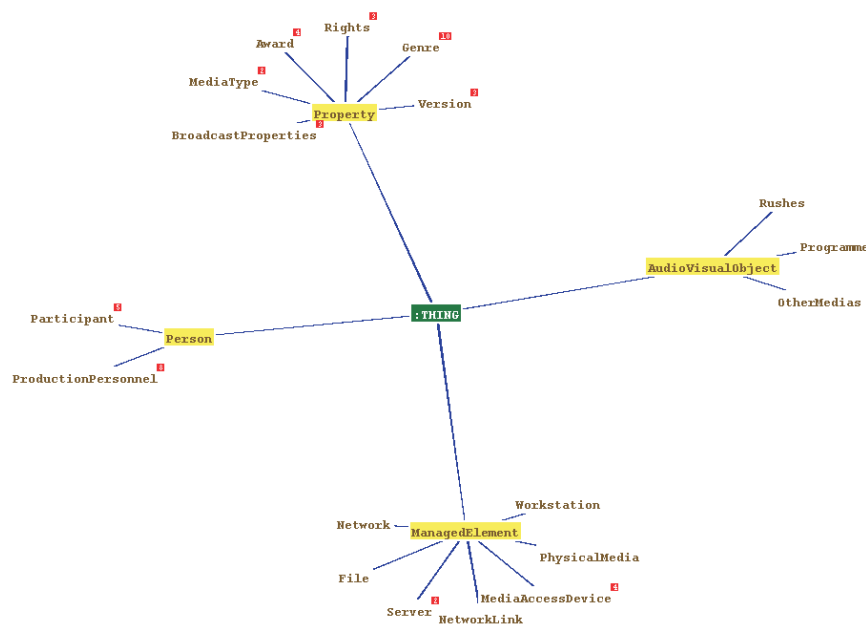


Figure 7.1: Partial view of the top levels of the Management Ontology

information on the content and that are available from most of the multimedia description schemas.

The ManagedElement

Management operations are to be performed over systems that make the archive operational. High level decisions, as the ones presented in the examples, will be based not only on the characteristics of the content but also on the hardware availability and its characteristics. The **ManagedElement** is used to describe manageable hardware or physical resources:

- a. The **MediaAccessDevice** class tries to catch the characteristics and manageability of all types of media access devices. A **MediaAccessDevice** represents the ability to access one or more media and use this media to store and retrieve data. This class has a set of subclasses that concretise the type of media the device is able to read (e.g a 16mm film, a 1" tape, a Betamax tape, a Umatic tape, etc). This class can be directly mapped to the **CIM:Device:MediaAccessDevice** class. A set of properties from this CIM class were selected based on its importance

concerning high level management decisions.

- b. The object of management in an archive is the content that is stored in tapes and films. The class **PhysicalMedia**, that can be directly mapped to **CIM:-Physical:PhysicalMedia**, represents any type of storage medium. This class is typically used to locate and manage Removable Media. It describes the main properties of those physical supports that might affect e.g. recycling priority (**has-mediaType**, **maxMounts**, **mountCount**, etc).
- c. The archive is deployed in a media area network requiring, then, the identification of each subnetwork (the class **Network** in this ontology). From the point of view of the high level management, this information is not directly relevant but will be required by the system for reasoning on the network load on the link that connects a **Workstation** and a **Server**.
- d. The **NetworkLink** class is a simplified version of the CIM specification for characterising network connections. From a business point of view, the manager is not interested in details of the technology but mainly on the aspects that enable an efficient management of the resources. This class re-uses concepts from the **CIM:Core:ActiveConnections** association and from the **CIM:Network:-ProtocolEndpoints** and **CIM:Network:NetworkPipe** classes as well as from other specific classes concerning communication technologies used. Each instance of this class represents a connection between two instances of a **Network** and includes information such as the **status** of the link, the **totalBandwidth**, the **ReservedBandwidth** or the **activeBandwidth**. The association **connects** is used to identify the two endpoint.
- e. The **Server** class catches the characteristics of the essence archives as defined in Section 5.2.2: the On-Line Archive (**OnlineServer**) and the Near-On-Line Archive (**NearOnlineServer**). A set of properties enables the identification of the location (**is-ConnectedTo**), characterisation of the storage capacity (**TotalManagedSpaced** and **RemainingManagedSpace**) as well as the definition of some management requirements like **LowSpaceWarningThreshold**. The **OnlineServer** maps to the **CIM:Device:StoragePool** class.
- f. Activities like annotation, browsing and editing are performed in a **Workstation** that **is-ConnectedTo** an instance of a **Network**.

- g. The `File` class is used to relate content available in an `OnlineServer` with an `AudiovisualObject` through the property `has-file`. The association `is-availableFrom` identifies the `Files` available from a `Server`.

An example of the associations between the classes `ManagedElement` and `AudiovisualObject` is presented in Figure 7.2. This view enables, for example, the association between an `AudiovisualObject` and a `MediaAccessDevice` that is able to read it through the associations `has-copy`, `is-stored-in`, `has-mediaType` and `is-Read-by`.

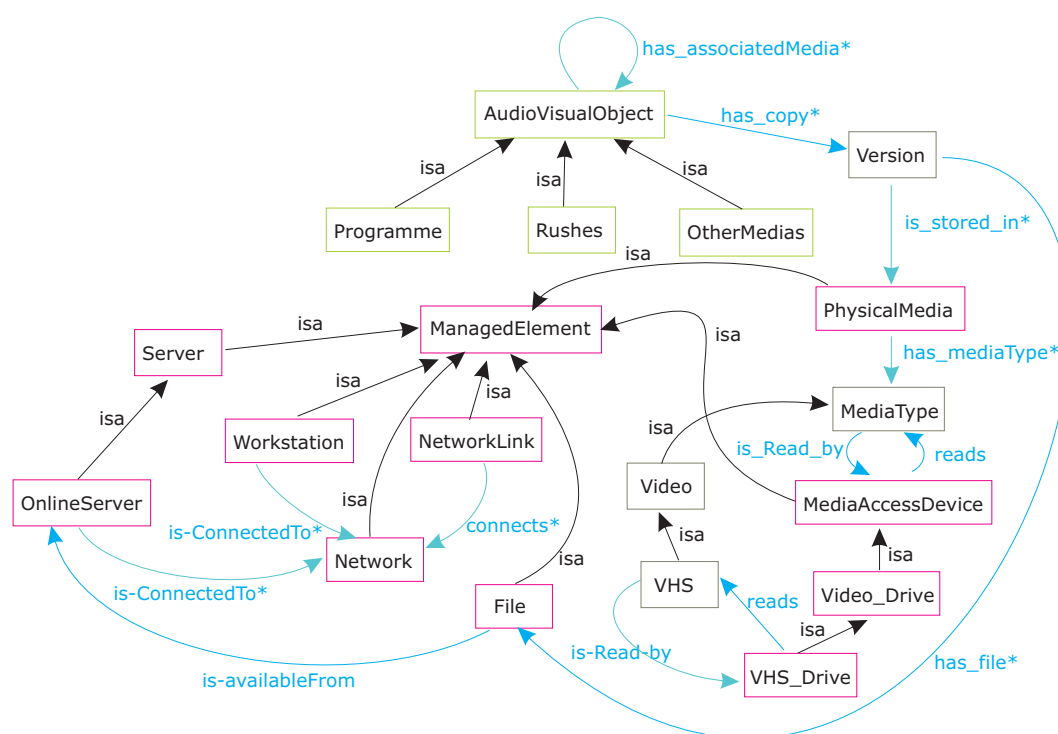


Figure 7.2: Partial view of the class `ManagedElement` and its association with the `AudiovisualObject` class

The Property

`AudioVisualObjects` will have a set of properties that enable additional information to characterise content. The main concepts that can be found on this branch of the hierarchy are:

- a. A classification of the content according to a set of themes (the `Genre` class).
The taxonomy defined for this ontology can easily be mapped to TV-Anytime

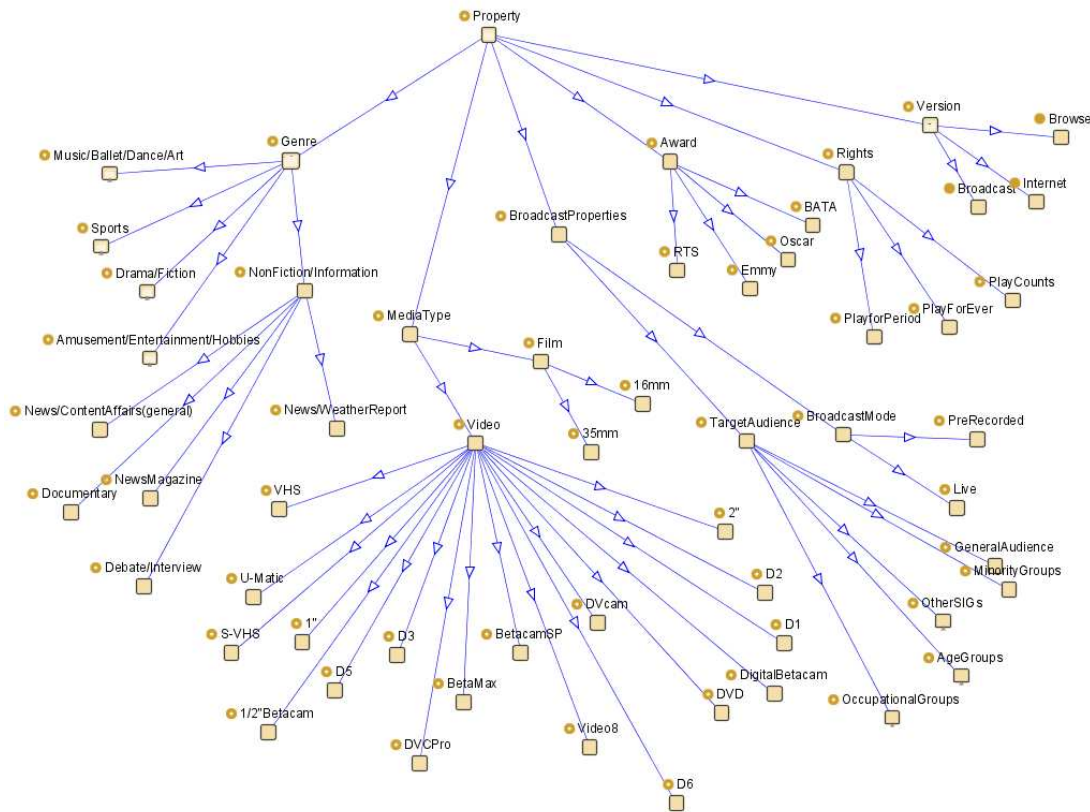
ContentCS [ETSI 2006a], EBU-Escort2.4 [EBU 1995] and DVB-EIT [ETSI 1998] classification schemes. A **Programme** can be catalogued e.g. as **NonFiction/Information**, **Drama/Fiction**, **Amusement/Entertainment/Hobbies**, **Music/-Ballet/Dance/Art** or **Sports** or, if more detailed information is wanted, as any subclass of these classes.

- b. Information concerning broadcast (e.g. **BroadcastMode** and **TargetAudience** is available under the **BroadcastProperties** class. Once again, for enabling an easy mapping with other ontologies, TV-Anytime and EBU-Escort2.4 were used as the basis for the target audience classification scheme (for example, **GeneralAudience** and **AgeGroups** are available classes with a set of subclasses that follow the existing taxonomies to classify the public).
- c. Decision e.g. on the need for preservation of a given content might be influenced by the list of awards that a **Programme** has. An association **has-award** between the classes **Programme** and **Award** is possible.
- d. The purchase type (**PlayForever**, **PlayforPeriod**, **PlayCounts**) can help the manager to signal content that should be re-used due to the fact that the owned rights are expiring. The hierarchy defined for the **Rights** class follows the classification scheme of the TV-Anytime standard.
- e. The architecture proposed in this thesis defines a set of different archives which support different content qualities (Section 5.2.2). The class **Version** reflects this classification and might be used, together with information concerning network load, to optimise resources (see Example 4 in 7.3.1). The slot **has-copy** enables the association of the classes **AudioVisualObject** and **Property:Version**.
- f. **MediaType** is an abstract class used to classify **PhysicalMedia** based on the type of tape/film used to store the content.

A partial view of the class **Property** and its subclasses is presented in the tree of Figure 7.3. To enable an easier reading, not all the hierarchy is presented in the picture.

The Person

The last part of the ontology contains the concepts that enable a **Person** to be associated with a **Programme** based on its role: technical staff can be identified through

Figure 7.3: Partial view of the class **Property**

the class **ProductionPersonnel** (which can be further classified e.g as a **Director** or **ScriptWriter**) while a participant in the programme is identified through the **Participant** class (which can also be specialised e.g as an **Interviewer** or an **InvitedGuest**). This class can be mapped to the **TVA:RoleCS** [ETSI 2006a] and **MPEG7:CS.RoleCS**.

Figure 7.4 presents a partial view of the hierarchy of the class **Person** and the relation of the class **Programme** with the top level classes.

7.4.2 Formalisation

The first step of the ontology construction, described in the previous section, enabled the definition of a set of key concepts and relationships that describe the domain of interest. The explicit representation, using a formal language, of the conceptualisation captured is the next phase defined in the methodology. This process involves committing to the basic terms that will be used to specify the ontology and choosing a representation language.

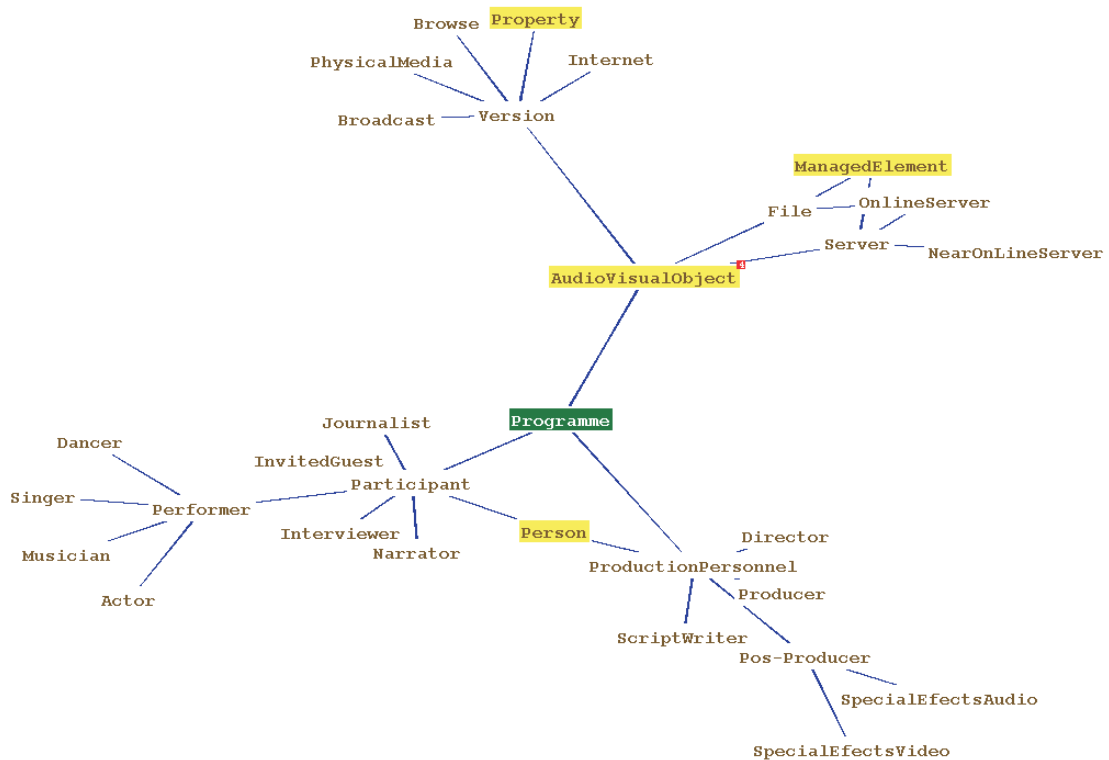


Figure 7.4: Partial view of the class **Programme** and its association with the top level classes

Metadata Representation Languages

The integration of the proposed domain ontology requires the definition of some mappings that relate this ontology with the underlying metadata resources. Most of the metadata models presented in Chapters 3 and 6 lack a formal representation that incorporates their explicit semantics and that can be used for automatic reasoning. Even those proposals that provide XML schemas, only partially capture some semantics of the domain they model as already noticed in [Hunter 2003], [Troncy 2003], [Troncy 2004], [Garcia and Òscar Celma 2005] and [Tsinaraki et al. 2005] in the multimedia domain or [Vergara et al. 2004a], [Lavinal et al. 2003] and [Quirolgico et al. 2004] in the networking domain.

Although XML [W3C 2006] and XML Schema [W3C 2004d] have been widely used to represent metadata, as they enable syntactic interoperability through data parsing, they fail in providing semantic interoperability as a great part of the semantics remain implicit.

Therefore, each time an application is developed, semantics must be extracted from the standard and re-implemented. Introducing new languages that fill the semantic gaps of XML has to be considered. In summary, the following characteristics can be assigned to each of the available languages:

- XML and XML schema — XML provides a mean to represent a structured document without imposing any semantic constraints while XML schema enables constraining the XML document structure. However, querying a XML database in order to retrieve e.g. a MPEG7 `SegmentType` description, requires that the application is aware of the hierarchy of segment types i.e. `VideoSegmentType`, `AudioSegmentType`, etc. [Garcia and Òscar Celma 2005]
- RDF and RDFS (RDF Schema) — RDF [W3C 2004b] is built upon XML and XML Schema and aims to provide a model that enables the description of the documents' semantic using the concept of resource and relations between those resources. RDFS [W3C 2004c] enriches RDF by enabling the definition of classes (`Class`) and properties (`Property`), range and domain constraints on properties, subclass (`subClassOf`) and subproperty (`subPropertyOf`) allowing the specification of a hierarchical organisation of classes and properties.
- OWL (Web Ontology Language) — OWL [W3C 2004a], layered on top of RDFS, adds capabilities to RDFS. It adds various constructors for building complex class expressions, cardinality restrictions on properties and mapping between classes and individuals such as `equivalentClass`, `sameAs`, `inverseOf`, etc [Antoniou and van Harmelen]. Reasoning is made possible as new knowledge may be inferred e.g. by transitivity. Querying an ontology doesn't require the user to have a global knowledge of the ontology schema.

It is clear from this summary that OWL enables greater flexibility when dealing with different metadata schemas as it provides richer descriptions that allow the formalisation of a domain and enable automated reasoning support. Adopting OWL for coding the management ontology proposed in this thesis enabled the definition of formal semantics for the concepts modeled in the previous step.

Some examples of the ontology proposed in this thesis, formalised using OWL, will be presented in the next section. These examples are expected to provide further information on the ontology and present the use of some of the functionalities offered by OWL.

Management Ontology Coding

A **Programme** was defined in the conceptualisation phase (see Section 7.4.1) as a subclass of the class **AudioVisualObject**. To assure that a piece of content is not classified both as a **Programme** and as one of the other subclasses of the **AudioVisualObject** class, the construct **disjointWith** was used. Table 7.1 defines these concepts using OWL.

Table 7.1: Definition of the concept **Programme** using OWL

1	<owl:Class rdf:ID="Programme">
2	<rdfs:subClassOf>
3	<owl:Class rdf:ID="AudioVisualObject"/>
4	</rdfs:subClassOf>
5	<owl:disjointWith>
6	<owl:Class rdf:ID="OtherMedias"/>
7	</owl:disjointWith>
8	<owl:disjointWith>
9	<owl:Class rdf:ID="Rushes"/>
10	</owl:disjointWith>
11	</owl:Class>

Video drivers (class **Video_Drive**) are one of the objects of management in a broadcast archive. Drivers are classified according to the technology implemented and defined as subclasses of the hierarchy **ManagedElement:MediaAccessDevice:Video_Drive**. Each type of drive can read only one type of tape and this information can be crucial for making decisions concerning tape migration due to lack of reading equipment. This aspect was coded using the OWL mechanisms for adding constraints to a property by declaring it as *functional*. Table 7.2 shows the use of the OWL term **owl:FunctionalProperty** and **owl:hasValue** to declare that a **Umatic_Drive** reads only **UMatic** tapes.

A similar restriction can be defined on the type of drive that is able to read a tape. Table 7.3 presents the use of the OWL construct **owl:inverseOf** to define such an inverse relation between properties. In this example, the property **reads** of the class **MediaAccessDevice** is defined as having an inverse property named **is-Read-by**.

Some properties of the defined ontology should not be allowed to have an arbitrary number of values. A **NetworkLink** is the concept used to characterise the connection between exactly two **Network** entities. Unless cardinality constraints are defined, OWL assumes that any instance of a class may have an arbitrary number of values for a given

Table 7.2: Restrictions on the property `reads` using OWL

```

1  <owl:Class rdf:about="#Umatic_Drive">
2    <rdfs:subClassOf rdf:resource="#Video_Drive"/>
3    <rdfs:subClassOf>
4      <owl:Restriction>
5        <owl:onProperty>
6          <owl:FunctionalProperty rdf:ID="reads"/>
7        </owl:onProperty>
8        <owl:hasValue>
9          <owl:Class rdf:about="#UMatic"/>
10       </owl:hasValue>
11     </owl:Restriction>
12   </rdfs:subClassOf>
13 </owl:Class>

```

Table 7.3: Definition of the property `is-Read-by` as the inverse property of `reads`

```

1  <owl:FunctionalProperty rdf:about="#reads">
2    <rdfs:domain rdf:resource="#MediaAccessDevice"/>
3    <rdfs:type rdf:resource="http://www.w3.org/2002/07/owl#ObjectProperty"/>
4    <owl:inverseOf>
5      <owl:FunctionalProperty rdf:about="#is-Read-by"/>
6    </owl:inverseOf>
7  </owl:FunctionalProperty>

```

property. A restriction on the property `connects` was defined to assure that the concept is clearly defined (Table 7.4).

7.4.3 Integration

Besides selecting the representation language, metadata integration methodologies have to be considered. This subject has been object of study in different areas as it is expected to allow the capitalization of existing semantic repositories by enabling share of data that exhibits a high degree of semantic heterogeneity, especially when related or overlapping data encompass different levels of granularity and distinct terminologies.

Having coded the ontology, the next phase requires the integration with other existing ontologies. This operation is often quite difficult but can be simplified if during the

Table 7.4: Definition of cardinality constraints for the `connects` property

1	<code><owl:Restriction></code>
2	<code> <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">2</code>
3	<code> </owl:cardinality></code>
4	<code> <owl:onProperty></code>
5	<code> <owl:ObjectProperty rdf:ID="connects"/></code>
6	<code> </owl:onProperty></code>
7	<code></owl:Restriction></code>

previous steps re-use of existing ontologies was considered.

Metadata Integration Methodologies

The problem of data merging lies at the core of many metadata applications. The goal is to obtain a global view of a set of schemas developed independently. As there are many different type of models and applications, this problem has, many times, been tackled independently in specific domains. A model, being a formal description, can be a database schema, a UML model, a message format or an ontology.

Initial work in this area was carried out in the database scientific field [Rahm and Bernstein 2001; Bernstein 2003]. Two proposed data integration methods are mediators and data warehouses [Aufaure et al. 2006]. While the first approach provides a global view by centralising relevant data, the mediator approach keeps the initial distribution of data. Each of these solutions has advantages and drawbacks and the choice between them must be done based on the application area and operational conditions.

The warehouse approach, although providing faster and easier access to data, requires content maintenance through periodical updates that may implement a full reconstruction of the warehouse or incremental updates.

By keeping the initial distribution of data, the mediator approach acts as an interface between users and data sources providing a transparent access to heterogeneous and distributed data sources.

Although the problem was first brought up by the database community, the same aspects of data integration have been recently studied in the ontology domain. It is unrealistic to expect that all organisations and application systems will use a common, shared ontology because 1) even if a particular ontology becomes favoured, there will

likely be many legacy solutions still in existence, which use an outmoded but still valid alternative, and 2) ontologies are usually aligned with a particular perspective. The need for ontology integration is then still a research area where some contributions have been made.

The problem of data integration requires usually the implementation of a human-mediated process and can pursue one of the following methods [Hameed et al. 2004]:

1. *Merging* aims at building a single new ontology that includes all information from all sources;
2. *Aligning* involves bringing two or more ontologies into a mutual agreement, making them consistent and coherent but kept separately. A set of alignment statements are created, which collectively define the relationships between the original ontologies;
3. *Integrating* entails building a new ontology by composing parts of other available ontologies. Like merging, this method results in a new ontology. However only parts of the original ontologies are considered.

The implementation of multiple ontology systems can be achieved through a set of alternative architectures [Hameed et al. 2004]:

1. *Pairwise mapping between individual ontologies* — In this architecture, illustrated in Figure 7.5a), there is no attempt to identify common conceptualisations and mapping is implemented only when there is a need to inter-relate individual ontologies. Although it is a simple approach, the number of mappings required may be large: $O(n^2)$ sets of mappings for n individual ontologies;
2. *Mapping to a single common ontology* — This approach, depicted in Figure 7.5b), requires the definition of a common ontology and mapping each of the individual ontologies to this upper one. By avoiding direct mappings between individual ontologies, reduces the number of sets of mappings to $O(n)$ for n ontologies. This solution requires, however, the development of a common ontology the enables mapping all the individual ontologies.
3. *Multiple ontology clusters* — A variant of the previous approaches consists in building clusters of inter-related ontologies, providing common conceptualisations, and in defining mappings between these clusters (Figure 7.5c)).

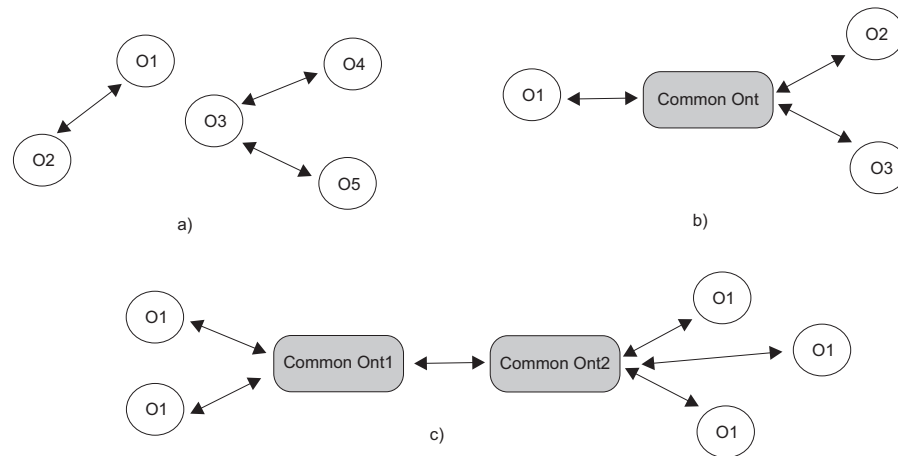


Figure 7.5: Ontology Mapping Architectures: a) Pairwise Mapping; b) Mapping to a Single Common Ontology; c) Multiple Ontology Clusters

Although a lot of work has been going on in this area, the process of ontology matching requires, usually, human intervention. Most methodologies that have been proposed to implement this action are based on linguist approaches (like name or description similarities), inheritance hierarchy, cardinality matching or constraint-based approaches (e.g. on data types, value ranges, etc) [Rahm and Bernstein 2001; Madhavan et al. 2003; Vergara et al. 2003, 2004b; de Vergara Méndez 2003]. Trying to improve this labor-intensive and error-prone process, some implementations, like GLUE [Doan et al. 2004], OntoBuilder [Roitman and Gal 2006] and oMAP [Straccia and Troncy 2005], have been published with the purpose of providing semi-automatic matching tools. The accuracy of these solutions is however limited and its application is restricted to mapping ontologies within the same domain.

Management Ontology Integration

The ontology proposed in this thesis provides an innovative approach by integrating concepts from multiple domains. This fact makes the process of using the semi-automated merging methodologies more difficult. Moreover, links between different domains have been defined during the conceptualisation phase to enable an integrated view of managed resources and content. This cross-domain integration is not provided in any of the existing ontologies making the automated mapping approaches not helpful. Furthermore, as the main purpose of the proposed ontology is to hide much of the detail of the underlying

metadata and to provide a business-driven management interface, only a small fraction of the metadata elements usually required to code each of the domains was considered.

The methodology used to define this BDIM ontology followed, nevertheless, some rules that are expected to simplify the integration mechanisms. As it can be seen from the examples presented on the conceptualisation phase (Section 7.4.1), the ontology tries to catch some concepts from existing schemas in both domains. This is clearly illustrated in the following tables that present the OWL code used to formalize some of the classes and properties of the proposed ontology.

Tables 7.5 and 7.6 present an extract of the OWL code of the class **PhysicalMedia** and the property **TotalManagedSpace** of the class **OnlineServer**. As it can be seen, information introduced in the conceptualisation phase is provided on the mapping proposal between these two concepts and the equivalent concepts in the CIM model.

Table 7.5: Mapping between the class **PhysicalMedia** and the CIM equivalent concept

1	<code><owl:Class rdf:ID="PhysicalMedia"></code>
2	<code><rdfs:subClassOf></code>
3	<code><owl:Class rdf:ID="ManagedElement"/></code>
4	<code></rdfs:subClassOf></code>
5	<code><rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string"></code>
6	Maps to CIM::Physical:PhysicalMedia. The PhysicalMedia class
7	represents any type of documentation or storage medium, such as tapes,
8	CDROMs, etc. This class is typically used to locate and manage
9	Removable Media.
10	<code></rdfs:comment></code>
11	<code></owl:Class></code>

Formal semantics of this data integration can be achieved by the definition of axioms that use the OWL construct **equivalentClass** or **equivalentProperty** as illustrated in Tables 7.7 and 7.8.

Some examples on the mapping proposals for a set of concepts that enable the characterization of content (namely the classes **Genre**, **Person**, **Rights** and the property **title**) are presented in Tables 7.9, 7.10, 7.11 and 7.12. This proposal aligns these concepts with equivalent concepts in the TVA, Escort, P/Meta, MPEG7, FIAT and DC standards presented in Chapter 3.

Table 7.13 presents the OWL code produced during the formalisation phase to link the property **title** that describes an **AudioVisualObject** and the DC element **Title**.

Table 7.6: Mapping between the property `TotalManagedSpace` and the CIM equivalent concept

```

1 <owl:FunctionalProperty rdf:ID="TotalManagedSpace">
2   <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
3     The total amount of capacity usable. Maps to CIM::Device
4     ::StorageServices::CIM.StoragePool.RemainingManagedSpace.
5   </rdfs:comment>
6   <rdfs:domain rdf:resource="#OnlineServer"/>
7   <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#int"/>
8   <rdfs:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
9 </owl:FunctionalProperty>

```

Table 7.7: Use of the `owl:equivalentClass` construct to map `PhysicalMedia` and `CIM:Physical:PhysicalMedia`

```

1 <owl:Class rdf:about="PhysicalMedia">
2   <owl:equivalentClass rdf:resource="#CIM;#PhysicalMedia"/>
5 </owl:Class>

```

7.5 Management Rules

The proposal presented in the previous sections describe the first layer of the management framework. The proposed approach is based on the definition of a unique information management model that aggregates information from different areas.

A second layer that is required to integrate this metadata was identified in Section 7.3.1. This new layer should add functionalities that facilitate business or high-level management decisions by defining restrictions or behavioural characteristics.

Table 7.8: Use of the `owl:equivalentProperty` construct to map the property `RemainingManagedSpace` and the equivalent concept in CIM

```

1 <owl:FunctionalProperty rdf:about="RemainingManagedSpace">
2   <owl:equivalentProperty rdf:resource="#CIM;#RemainingManagedSpace"/>
3 </owl:FunctionalProperty>

```

Table 7.9: Mapping between the class **Genre** and equivalent concepts in a set of standard description schemas

```

1  <owl:Class rdf:about="#Genre">
2    <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
3      This dimension is used to classify programmes according to their content
4      or subject. According to TVA:ContentCS, TVA:FormayCS, EBU:Escort2.4:Format,
5      EBU:Escort2.4:Content, DVB:EIT, EBU:P/Meta:EDITORIAL_FORMAT_CODE
6      and MPEG7:CreationInformation.Classification.Genre.
7    </rdfs:comment>
8    <rdfs:subClassOf rdf:resource="#Property"/>
9  </owl:Class>

```

Table 7.10: Mapping between the class **Person** and equivalent concepts in TVA and MPEG7

```

1  <owl:Class rdf:about="#Person">
2    <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
3      Maps to TVA:RoleCS and MPEG7:CS.RoleCS.
4    </rdfs:comment>
5  </owl:Class>

```

The language used to formalise the ontology contains all the constructors needed to formally describe management definitions. However, it doesn't provide functionalities to express rules or behavior.

7.5.1 SWRL: a language for defining rules for OWL ontologies

The Semantic Web Rule Language (SWRL)[Horrocks et al. 2004] allows users to write rules that can be expressed in terms of OWL concepts and that can reason about OWL individuals. By using this language, interoperability is achieved as both content and resource management metadata as well as rules are expressed in the same language. This enables rules to be saved as part of the ontology. Moreover, a development environment — the SWRL-Tab [O'Connor et al. 2005, 2007] — is provided to be integrated within the *Protégé* suite that was used to model the ontology proposed in this thesis.

SWRL rules are written as an implication between an 'antecedent' (*body*) and 'consequent' (*head*) pairs: whenever the conditions specified in the antecedent hold, then

Table 7.11: Mapping between the class `Rights` and the TVA equivalent concept

```

1  <owl:Class rdf:about="#Rights">
2    <rdfs:subClassOf rdf:resource="#Property"/>
3    <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
4      Maps to TVA:PurchaseTypeCS. Defines quantity units to further
5      qualify a purchase type in "days", "months" or "years" for a
6      period of time and "plays"for a number of plays.
7    </rdfs:comment>
8  </owl:Class>

```

Table 7.12: Mapping between the property `title` and equivalent concepts in a set of standard description schemas

```

1  <owl:FunctionalProperty rdf:ID="title">
2    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
3    <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
4    <rdfs:domain rdf:resource="#AudioVisualObject"/>
5    <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
6      A name given to the resource. Maps to DC.Title, FIAT:MDL.Title,
7      SMPTEdictionary:Title, MPEG7:CreationInformation.Creation.Title and
8      TVA:BasicContentDescriptionType.Title.
9    </rdfs:comment>
10 </owl:FunctionalProperty>

```

the conditions specified in the consequent must also hold. The head and body consist of a conjunction of one or more atoms. Atoms can be of the form `C(x)`, `P(x,y)`, `sameAs(x,y)` or `differentFrom(x,y)`, where `C` is an OWL description, `P` is an OWL property, and `x,y` are either variables, OWL individuals or OWL data values. A set of different built-ins is also available enabling comparisons (e.g. `swlrb:lessThan`), mathematical operations (e.g. `swlrb:add`), operations on strings (e.g. `swlrb:stringConcat`) or dates (e.g. `swlrb:date`). SWRL rules can also be used to query OWL ontologies (e.g. `sqwrl:select`).

Table 7.14 presents some examples of the use of SWRL built-ins to query the management ontology defined. The first rule queries the ontology to count all the available drives (class `Video_Drive`) that read (property `reads`) Umatic (class `Umatic`) tapes. In the second example, all the tapes (class `PhysicalMedia`) that were mounted (property

Table 7.13: Use of the `owl:equivalentProperty` construct to map `title` and `DC:Title`

```

1  <owl:FunctionalProperty rdf:ID="title">
2    <rdfs:domain rdf:resource="#AudioVisualObject"/>
3    <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
4    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
5    <owl:equivalentProperty rdf:resource="&DC;#Title"/>
6  </owl:FunctionalProperty>

```

`mountCount`) more than 50 times are presented in descend order. The third rule enables the selection of all programmes (class `Programme`) that received an RTS award (property `has-award` has the value `RTS`) and have as Director a given person (property `has-team` has a value that belongs to the class `Director`).

Table 7.14: Example of SWRL rules that perform queries on the Content and SRM ontologies

```

Rule 1:  Video_Drive(?x) ∧ reads(?x, UMatic) → sqwrl:count(?x)
Rule 2:  PhysicalMedia(?x) ∧ mountCount(?x, ?y) ∧ swlrb:greaterThan(?y, 50)
        → sqwrl:select(?x, ?y) ∧ sqwrl:orderByDescending(?y)
Rule 3:  Programme(?x) ∧ has-award(?x, RTS) ∧ has-team(?x, person3)
        ∧ abox:hasClass(person3, Director) → sqwrl:select(?x)

```

7.5.2 Integrating different domains using SWRL

The examples above illustrate the use of SWRL to define rules and to query the ontology concerning aspects of content or resource management. Some preliminary experiences have also been developed by [Guerrero et al. 2005] and [Xu and Xiao 2006] in order to formalise behavior implicitly defined in some SNMP MIBs. However, as argued before in this thesis, the integration of both domains is expected to provide extra information and functionalities to a management application that aggregates knowledge usually spread among different systems. The first step towards this integrated view was achieved by defining an upper level ontology that isolates the manager from the underlying details and provides information that enables the development of an efficient and business driven management platform. This section presents some examples of the use of SWRL and the

proposed integrated ontology to solve some of the problems detected in Section 7.3.1.

Example 1 in Section 7.3.1

The problem described in ‘Example 1’ in Section 7.3.1 requires the integration of two domains: a file should be seen not only as an object managed by the storage devices but also as an object that has an identity in the domain of content.

MRule 1: $AudioVisualObject(?a) \wedge File(?f) \wedge is_fileVersion_of(?f, ?a) \wedge$
 $timeOfLastAccess(?a, ?t)$
 $\rightarrow sqwrl:select(?f, ?t) \wedge sqwrl:orderByDescending(?t)$

Example 2 in Section 7.3.1

‘Example 2’ in Section 7.3.1 defines a guideline for recycling prioritisation based on information available in the two domains. The process should be driven by the number of times a tape was mounted and the type of content it holds. The rule below formalises this requirement by selecting all the News Magazines that are stored in tapes mounted more than 50 times. The ‘head’ of the rule will provide the manager with a list of ordered items that provide the identification of the tape and the name of the programme selected.

MRule 2: $PhysicalMedia(?x) \wedge mountCount(?x, ?y) \wedge swrlb:greaterThan(?y, 50) \wedge$
 $Programme(?a) \wedge has_genre(?a, NewsMagazine) \wedge has_award(?a, RTS) \wedge$
 $has_copy(?a, ?b) \wedge is_stored_in(?b, ?x)$
 $\rightarrow sqwrl:select(?x, ?y, ?a) \wedge sqwrl:orderByDescending(?y)$

More complex requirement can easily be added to the rule by providing extra atoms with additional constrains. By adding a simple atom to the previous rule (see MRule 2a), the search is narrowed to a defined type of tapes.

MRule 2a: $PhysicalMedia(?x) \wedge mountCount(?x, ?y) \wedge swrlb:greaterThan(?y, 50) \wedge$
 $Programme(?a) \wedge has_genre(?a, NewsMagazine) \wedge has_award(?a, RTS) \wedge$
 $has_copy(?a, ?b) \wedge is_stored_in(?b, ?x) \wedge has_MediaType(?x, DigitalBetacam)$
 $\rightarrow sqwrl:select(?x, ?y, ?a) \wedge sqwrl:orderByDescending(?y)$

The definition of auxiliary rules help simplifying the management rules to be used by the top manager. The rule below, defines a new property (**has-format**) based on the combination of the properties **has-copy**, **is-stored-in** and **has-mediaType**.

ARule 1: $has-copy(?x, ?y) \wedge is-stored-in(?y, ?z) \wedge has-mediaType(?z, ?t)$
 $\rightarrow has-format(?x, ?t)$

By using this new property, MRule 2a, can be simplified:

MRule 2a1: $PhysicalMedia(?x) \wedge mountCount(?x, ?y) \wedge swlrb:greaterThan(?y, 50) \wedge$
 $Programme(?a) \wedge has-genre(?a, NewsMagazine) \wedge has-award(?a, RTS) \wedge$
 $has-format(?a, DigitalBetacam)$
 $\rightarrow sqwrl:select(?x, ?y, ?a) \wedge sqwrl:orderByDescending(?y)$

Example 4 in Section 7.3.1

The problem described in ‘Example 4’ in Section 7.3.1 highlights the need of knowledge sharing about network conditions and version of content. The following rule defines the conditions for selecting a low quality version of a media object based on the available bandwidth. The criterium used for selecting a browse version is that a predefined threshold was reached. Similar rules can be defined for other versions of content.

MRule 4: $Programme(?x) \wedge has-copy(?x, ?c) \wedge abox:hasClass(?y, Browse) \wedge$
 $is-available-from(?x, ?s) \wedge is-ConnectedTo(?s, ?n) \wedge$
 $Workstation(?w) \wedge is-ConnectedTo(?w, ?n) \wedge$
 $NetworkLink(?nlink) \wedge connects(?nlink, ?n) \wedge$
 $availableBandwidth(?nlink, ?bd) \wedge swrl:lessThanOrEqual(?bd, 500)$
 $\rightarrow sqwrl:select(?c)$

Example 5 in Section 7.3.1

As the SRM is blind concerning the relation between two pieces of content, the availability of a property in the ontology (**has-associatedMedia**) that relates different media objects, can be used to solve the problem stated in ‘Example 5’. Migration of content is then ruled

by the properties `RemainingManagedSpace` and `LowSpaceWarningThreshold` of the class `OnlineServer` together with knowledge about content:

MRule 5: $OnlineServer(?x) \wedge RemainingManagedSpace(?x, ?y) \wedge$
 $LowSpaceWarningThreshold(?x, ?z) \wedge swlrb:lessThan(?y, ?z) \wedge$
 $AudioVisualObject(?a) \wedge is-available-from(?a, ?x) \wedge$
 $has-associatedMedia(?a, ?b) \wedge timeOfLastAccess(?a, ?t)$
 $\rightarrow sqwrl:select(?a, ?b) \wedge sqwrl:orderBy(?t)$

7.5.3 Extending SWRL to allow complex Rule definition

The previous section illustrates the use of SWRL as the integrating language in the domain of study. Although this language is quite powerful and provides the mechanisms for implementing a set of different operations on ontologies, some useful functionalities that would increase its applicability in the management areas as the one that has been studied in this thesis are still missing.

Based on our experience on the domain, some proposals for extending the language are presented. These proposals will be illustrated by some examples taken from the requirements drawn in this thesis.

As briefly explained, SWRL is based on the combination of a number of atoms that allow the definition of rules or querying an ontology using a set of pre-defined constructors. However, the language doesn't predict the need of using built-in functions as variables. This combination/aggregation of functions would provide extra functionalities to the management applications and would allow the simplification of the defined rules.

To illustrate this need we take 'Example 3' in Section 7.3.1: tape transcription is dictated by hardware obsolescence and the genre of content. Although partial analysis can be done, the simplest approach would be to use complex queries that enable the aggregation of functions. The following rule illustrates the need of these constructors in the SWRL language:

MRule 3: $Programme(?x) \wedge has-genre(?x, ?y) \wedge$
 $tbox:isDirectSubClassOf(?y, NonFiction_Information) \wedge has-copy(?x, ?a) \wedge$
 $is-stored-in(?a, ?b) \wedge has-mediaType(?b, ?c) \wedge Video_Drive(?k) \wedge$
 $reads(?k, ?c) \wedge swlrb:lessThan(sqwrl:count(?k), 2)$

$$\rightarrow \text{swrl:select}(?k) \wedge \text{swrl:orderByDescending}(?k)$$

The purpose of this rule is to provide the manager with a list of tapes that should undergo a transcription process due to the fact that they hold programmes that are classified as **NonFiction-Information** and the number of devices available for reading them is reduced (less than two). This query requires the combination of different functions and the use of SWRL built-ins as parameters (`swrlb:lessThan(swrl:count(?k), 2)`). This functionality, not available in the SWRL language, would provide more efficient reasoning. By allowing this type of constructs, rules could be further simplified as illustrated in the following example:

MRule 3a: *Programme*(?x) $\wedge$
 $\text{has-genre}(?x, \text{tbox:isDirectSubClassOf}(?y, \text{NonFiction_Information})) \wedge$
 $\text{has-copy}(?x, ?a) \wedge \text{is-stored-in}(?a, ?b) \wedge \text{has-mediaType}(?b, ?c) \wedge$
 $\text{Video_Drive}(?k) \wedge \text{reads}(?k, ?c) \wedge \text{swrlb:lessThan}(\text{swrl:count}(?k), 2)$
 $\rightarrow \text{swrl:select}(?k) \wedge \text{swrl:orderByDescending}(?k)$

7.6 Ontology population and validation

Validation of the ontology concepts and of the rules defined was achieved by populating the ontology with a set of instances for each of the defined classes.

Figure 7.6 presents a partial view of the description of an instance of a programme¹. Besides providing information concerning the characterisation of the content, the different available versions are also identified together with the tapes where they are stored in: the **Programme** identified as **News20071018** was a **Live** emission whose target audience is **GeneralAudience**, has no rights associated (**PlayForever**) and has a set of people participating having different roles; the content is available as full quality from **Tape 2** (a **Digital Betacam** tape) and as browse quality from **Tape 4** (a **VHS** tape).

A different view of the ontology (Figure 7.7) provides information about the availability of the broadcast quality version of this content from an Online Server (**OnLineServer1**)

¹Instances of the ontology are presented in red while classes are pictured in brown.

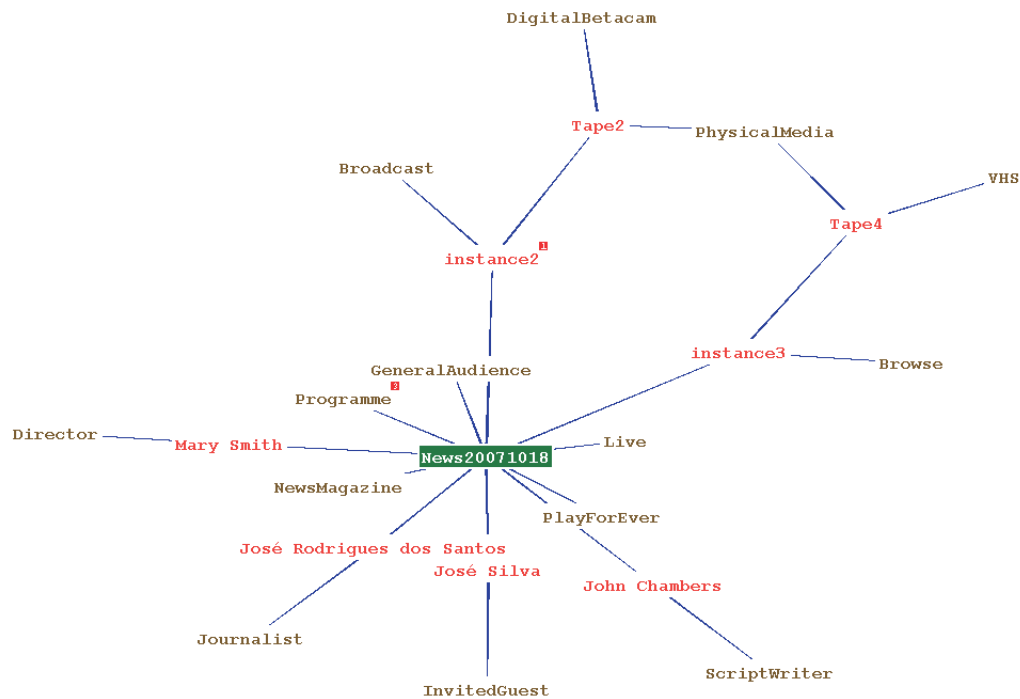


Figure 7.6: View 1 of the description of a *Programme* instance (News20071018)

connected to **Network1** or about the availability of drivers to read the programme video formats (Figure 7.8).

This example provides a clear view of the integration of content description and resource description metadata and of its applicability to solve ‘Example 3’ in Section 7.3.1. ‘Example 2’, uses additional properties available from the class `ManagedElement.PhysicalMedia` as defined by ‘MRule 2’.

Tests were conducted to validate the integration of the information, the rules defined and the use of the coding languages.

7.7 Concluding remarks

The previous chapters presented various proposals concerning the description of audiovisual objects and manageable elements. This chapter presents some examples that demonstrate the complexity of building a management application based on business objectives due to the diversity of models, their complexity and the lack of integration of the different

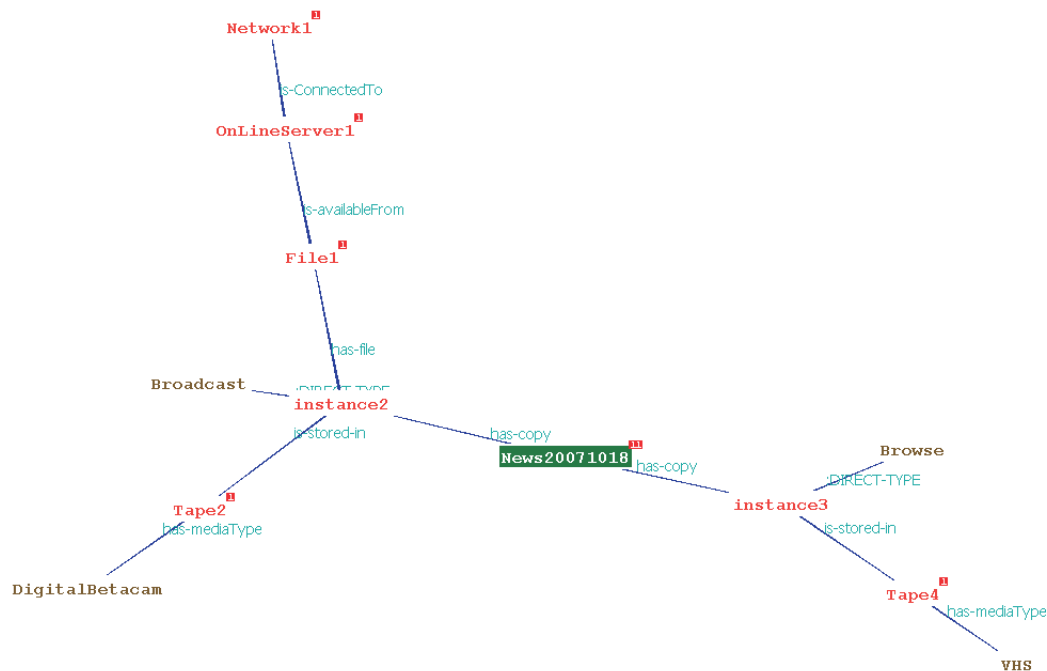


Figure 7.7: View 2 of the description of the instance (News20071018) — availability

worlds.

The work described in this chapter introduces a proposal that defines a domain ontology that is expected to provide the mechanisms for enabling the development of a business driven archive management application.

Its key ideas are the definition and formalisation of an ontology that inherits the main concepts from the existing description models but reduces the complexity and number of entities. Moreover, it combines concepts from different worlds allowing the integration of information that provides the mechanism for decision making.

The method for the integration of this model with the underlying schemas is justified based on the deep knowledge of this business area. A mapping example is also provided showing how this domain ontology may be integrated in different scenarios.

On top of this new layer that defines a unique information management model, a second layer that adds functionalities expected to facilitate high level management decisions is proposed. This new layer provides mechanisms to express rules or behaviour and can be used as input to a management application.

By formalising the ontology in OWL and using SWRL to define a set of rules that

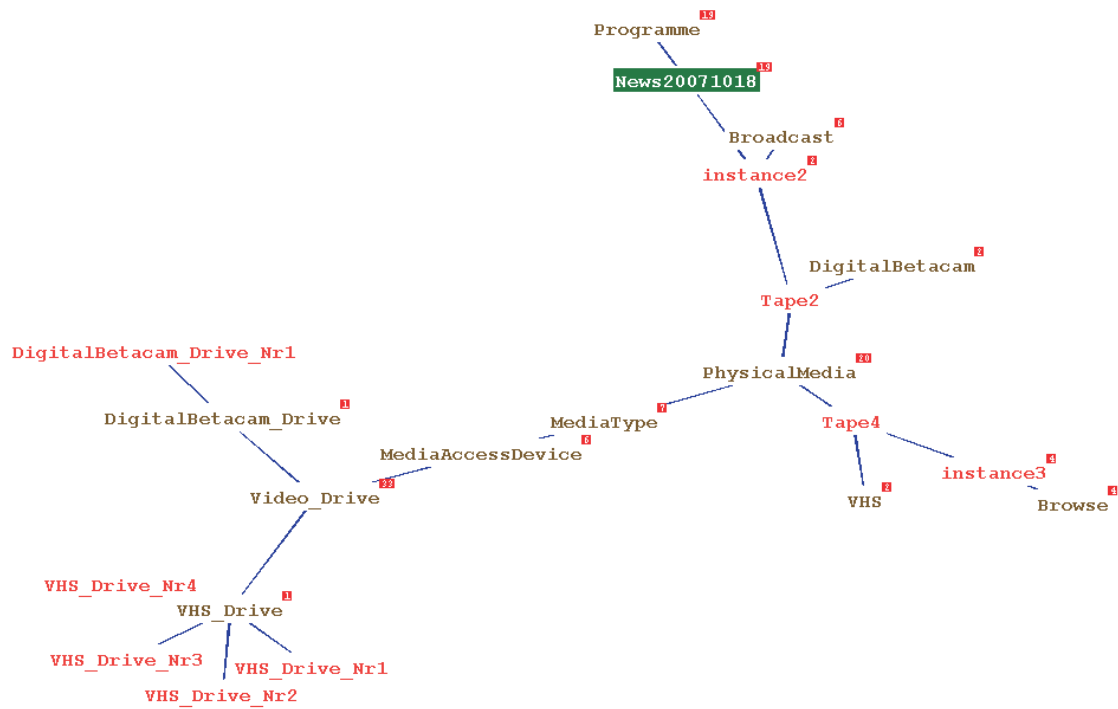


Figure 7.8: View 3 of the description of the instance (News20071018) — media access devices

are expected to simplify the integrated management of content and resources, all the knowledge is kept in the same domain and can be extended for specific needs.

Evaluation and validation of the concepts was achieved by populating the ontologies with entities from both domains and by defining and running a set of rules that define usual requirements from a high level management layer.

Chapter 8

Conclusions

This chapter draws a set of conclusions, reviews the main contributions of the thesis and gives some guidelines for future work in this area.

8.1 Overview

The main objective of this thesis, as stated in Chapter 1, was to propose strategies that will enable the effective deployment of complex networked audiovisual archives in Broadcaster environments.

Due to the complexity of the problem, different topics of research had to be considered. The first major one, deals with the problem of describing multimedia objects. Different solutions have been proposed by the research community as metadata is usually not only content but also domain-dependent. This means that different sub-sets and variations have been designed for a specific audiovisual application or use, or focusing on specific aspects of the production chain. Most of the times, these initiatives were developed separately and resulted in quite different structures and level of detail.

The second main area of research dealt with the problem of management devices and resources in a complex networked MAM system. The main problem encountered was the diversity of protocols and models and the lack of an integrated view as most of the proposals deal with very specific areas of application and cannot be directly applied to the object of study of this thesis. Although some proposals have been introduced by the ‘Media’ research community, the most important contributions towards a unified model

came from the ‘Networking’ community.

The need for an integrated approach was identified during the work development: there were no proposals that dealt with the problem of integrating both views and the partial solutions available could not deal with the problems detected.

8.2 Contributions of the thesis

The general objectives of this thesis, stated in Chapter 1, were to present worthy contributions for an effective usage of the media archives in broadcaster environments. It is the author’s opinion that, globally, those objectives were achieved, leading to the following major contributions:

- i. This document presented as a thesis is expected to be a valuable starting point to anyone willing to work in the area of Digital Television or, more precisely, Media Asset Management in Broadcaster environments. One of the problems encountered, when we start working in this subject, was the lack of bibliography that would help understanding the problem that big broadcast archives face. Not only there is not a lot of documentation describing the working processes but, also, there is not a lot of references that are able to introduce the different topics of research. By presenting an integrated and broad view of such different aspects that are usually dealt with by different communities not aware of the other point of view, this document is unique and of great interest.
- ii. A generic architecture that was deployed in a real world environment and that, by integrating concepts that come from different metadata communities and by adapting them to a concrete application area, provides a good proposal for a MAM system architecture in a Broadcaster environment.
- iii. Mapping proposals of different description schemas. By dealing with a large number of approaches, this thesis gives an integrated view of metadata schemes and discusses the mapping possibilities. By providing this diversity of mappings, other proprietary solutions can be easily integrated by just defining its mapping to one of the available schemes.
- iv. A domain ontology that, by providing an upper level view of the system, is expected to isolate management applications from the underlying details and

facilitate the definition of business or high-level decisions concerning the effective management of broadcast archives. By providing mapping proposals between the defined classes and properties and some of the most important underlying standard metadata schemas, this ontology can be easily integrated with any system without the need of direct mapping.

- v. The integration of proposals and concepts from different domains providing and integrated view of content and resources metadata as well as of management decisions or behavior by using semantic web languages and tools.

8.3 Guidelines for future research

The results presented in this thesis, concerning the integration of content and device description metadata, make us believe that this is a promising approach towards the definition of a unified interface for the effective management of broadcast archives. The work presented here had as application field the broadcast archives that, due to the amount of content owned, complexity of the process and existing legacy equipment, require the development of complex solutions. Assessing the applicability of a similar strategy to other business areas like small media companies or museums, should be investigated.

Furthermore, and focusing on the semantic web technologies used, one should investigate the use of OWL-S (Semantic Markup for Web Services)[Martin et al. 2004] to describe services capable of implementing some of the rules formalised in SWRL. By defining rules that would automatically call available services, management processes could be automated as already noticed in [Vergara et al. 2005] and [Xu and Xiao 2007] for network management. The coordination of OWL, SWRL and OWL-S could then contribute to the automation of some of the business driven media asset management processes.

Another gap encountered during the implementation phase was the impossibility of defining complex rules using built-in functions as parameters. Improving SWRL-Tab to support these composite queries would provide developers an useful tool for the definition of more user friendly and readable rules.

Several lines of research may therefore be drawn, supported by the contributions of this thesis and in depth research work may be developed. Some of those lines of research are proposed here structured as set of plans for MSc dissertations or pre-thesis in a Doctoral programme.

8.3.1 Plan A: Media Asset Management strategies for small scale archives

Scope and Objectives

The present situation of the television archives and the need to urgently define mechanisms for reducing tape handling in the archive, intensive staff work, distribution of unwanted media by allowing users to preview selected material, and the need for enabling faster documentation and to provide the technical basis for electronic commerce and re-purpose of archive material, requires the implementation of Digital Media Asset Management systems in the Broadcasters' premises.

However, given the complexity of the workflow and of the required systems, deployment in real environments showed that additional functionalities should be developed to provide decision makers a high level interface that would hidden the complex implementation and facilitate their business driven decisions to be taken.

The aim of this dissertation is to identify activity areas, other than the Broadcasters, where the deployment of MAM systems may help their ongoing business lines or even raise new opportunities. This research should take into account the conclusions achieved concerning the deployment problems in large scale archives and should study the application of a similar strategy in these new application areas. [Klijn and de Lusenet 2008] provides information that help on the characterisation of audiovisual archives, other than broadcasting. It contains facts and data from 374 organisations from 34 European countries that range from museums, libraries and archives to private collectors and commercial companies. The focus of this report is on the mixed-media collections in non-specialist institutions. Many of the collections under study are small or very small: 65% of film and around 40% of audio and video collections consist of no more than 500 hours. However, even if they are small, they still represent significant value.

Plan Outline

Phase 1 (duration 1 months) – analysis of the strategy proposed in this thesis for the management of Broadcaster archives.

Phase 2 (duration 2 months) – analysis of the current situation and of new requirements for small scale archives. This phase should be driven by real world examples and by direct contacts with asset owners.

Phase 3 (duration 6 months) – consolidation of the information and adaptation of the

existing proposal to the new cases.

Phase 4 (duration 2 months) – synthesis of the results and writing of dissertation.

8.3.2 Plan B: Automating management operations using SWRL and OWL-S

Scope and Objectives

Current resource management approaches use different models, languages and protocols to manage devices and resources. This leads to an interoperability problem that can be solved by using OWL and SWRL as the framework for defining objects and management rules. However, although the former approaches provide also mechanisms for defining operations on the managed objects, OWL lacks the mechanisms for implementing these methods.

The objective of this thesis is to study the integration of actions in the management ontology defined for the Broadcasting environment using OWL-S.

Plan Outline

Phase 1 (duration 1 months) – familiarisation with the OWL family of languages and associated development environments.

Phase 2 (duration 1 months) – analysis of the ontology for MAM in broadcasting environments.

Phase 3 (duration 1 months) – definition of the OWL-S services to be developed and integrated in the ontology.

Phase 4 (duration 6 months) – development and integration of a number of selected services.

Phase 5 (duration 1 months) – testing of the developed tool with different test cases.

Phase 6 (duration 2 months) – synthesis of the results and writing of dissertation.

8.3.3 Plan C: Improving SWRL-Tab to support complex queries

Scope and Objectives

Ontologies are used to capture knowledge about some domain of interest. An ontology describes the concepts in the domain and also the relationships that hold between those concepts. Different ontology languages provide different facilities.

OWL (Web Ontology Language) is a standard ontology languages proposed by the World Wide Web Consortium (W3C) that, by providing additional vocabulary, extends the functionalities of XML, RDF and RDF schema and enables the formalisation of ontologies.

The Semantic Web Rule Language (SWRL) allows users to write rules that can be expressed in terms of OWL concepts and that can reason about OWL individuals.

By using these two languages, the integration of Content description and Resource description knowledge can be achieved and management action are expected to be improved.

Protégé 2000 is an integrated software tool used by system developers and domain experts to develop knowledge-based systems. Applications developed with *Protégé 2000* can be used in problem-solving and decision-making in a particular domain. This framework enables the integration of externally developed tools that enhance the available functionalities. The *Protégé SWRL Editor* — SWRL-Tab — is a highly interactive open-source rule editor for SWRL that operates within *Protégé* and is tightly integrated with it.

The main objective of this dissertation is to enhance the SWRL Tab by allowing the definition of composite rules that support the use of SWRL built-ins as parameters.

Plan Outline

Phase 1 (duration 1 months) – literature survey on the state of the art of ontology languages and available development tools.

Phase 2 (duration 2 months) – analysis of the *Protégé* and SWRL-Tab source code and development methods.

Phase 3 (duration 6 months) – design and implementation of the SWRL-Tab new functionalities.

Phase 4 (duration 1 months): exhaustive testing of the developed tool with different ontologies.

Phase 5 (duration 2 months) – synthesis of the results and writing of dissertation

8.3.4 Plan D: Management User Interface

Scope and Objectives

Managing complex media archives from a business point of view is a difficult task as the amount of details provided by the metadata schemas used to describe media objects and resources prevent managers from having an integrated view of the system. The definition of an upper metadata layer that isolates the high level manager from the implementation details is expected to work as a framework to enable the implementation of a new management tool. The main objective of this thesis is to develop and test a graphical user interface that, by using the proposed ontology, provides an user friendly tool that enables the implementation of high level integrated decisions.

Plan Outline

Phase 1 (duration 1 months) – familiarisation with the OWL family of languages and associated development environments.

Phase 2 (duration 1 months) – analysis of the ontology for MAM in broadcasting environments.

Phase 3 (duration 1 months) – definition the main functionalities to be provided by the management tool.

Phase 4 (duration 6 months) – development of the user interface and integration with the underlying environment.

Phase 5 (duration 1 months) – testing of the developed tool with different test cases.

Phase 6 (duration 2 months) – synthesis of the results and writing of dissertation.

Appendix A

Management Ontology Documentation

This Appendix provides the documentation of the Management Ontology defined. The list of Classes and Properties is presented together with a small description, and their relations with the other entities. To enable an easier mapping with underlying metadata schemas, some mapping examples are also supplied.

A.1 Class Documentation

▣ **AudioVisualObject**

- ⊙ *Documentation*: An AudioVisualObject is a piece of content, whatever is its type, format and processing status.
- ⊙ *SubClasses*: **Programme**, **Rushes**, **OtherMedias**
- ⊙ *DomainOf*: **has-associatedMedia**, **has-copy**, **productionDate**, **synopsis**, **timeOfLastAccess**, **title**.

▣ **Actor**

- ⊙ *Documentation*: An entertainer who performs a dramatic or musical work for audience.
- ⊙ *SuperClasses*: **Performer**

▣ **Award**

- ⊙ *Documentation*: List of awards that a programme has won, or been nominated for. Decision e.g. on the need for preservation of a given content might be influenced by the list of awards that a **Programme** has. An association **has-award** between the classes **Programme** and **Award** is possible.

- ⊙ *SuperClasses*: Property
- ⊙ *SubClasses*: Oscar, Emmy, BATA, RTS

▣ **BetacamSP**

- ⊙ *Documentation*: Abstract class that represents the BetacamSP video format.
- ⊙ *SuperClasses*: Video
- ⊙ *DisjointWith*: 1", 2", 1/2"Betacam, BetaMax, D1, D2, D3, D5, D6, DigitalBetacam, DVCPro, DVcam, S-VHS, U-Matic, Video8, VHS, DVD.
- ⊙ *DomainOf*: is-Read-by

▣ **BetacamSP_Drive**

- ⊙ *Documentation*: BetacamSP Drive
- ⊙ *SuperClasses*: Video_Drive
- ⊙ *DisjointWith*: 1_2_Betacam_Drive, 1_Drive, 2_Drive, BetaMax_Drive, CDROM_Drive, D1_Drive, D2_Drive, D3_Drive, D5_Drive, D6_Drive, DigitalBetacam_Drive, DVD_Drive, SVHS_Drive, Umatic_Drive, VHS_Drive, Video8_Drive.
- ⊙ *DomainOf*: reads

▣ **BetaMax**

- ⊙ *Documentation*: Abstract class that represents the BetaMax video format.
- ⊙ *SuperClasses*: Video
- ⊙ *DisjointWith*: 1", 2", 1/2"Betacam, BetacamSP, D1, D2, D3, D5, D6, DigitalBetacam, DVCPro, DVcam, S-VHS, U-Matic, Video8, VHS, DVD.
- ⊙ *DomainOf*: is-Read-by

▣ **BetaMax_Drive**

- ⊙ *Documentation*: BetaMax Drive
- ⊙ *SuperClasses*: Video_Drive
- ⊙ *DisjointWith*: 1_2_Betacam_Drive, 1_Drive, 2_Drive, BetacamSP_Drive, CDROM_Drive, D1_Drive, D2_Drive, D3_Drive, D5_Drive, D6_Drive, DigitalBetacam_Drive, DVD_Drive, SVHS_Drive, Umatic_Drive, VHS_Drive, Video8_Drive.
- ⊙ *DomainOf*: reads

▣ **Broadcast**

- ⊙ *Documentation*: Broadcast quality version of an AudioVisualObject
- ⊙ *SuperClasses*: Version

▣ **BroadcastProperties**

⊙ *Documentation*: Information concerning broadcast (e.g. `BroadcastMode` and `TargetAudience` is available under the `BroadcastProperties` class. Once again, for enabling an easy mapping with other ontologies, TV-Anytime and EBU-Escort2.4 were used as the basis for the target audience classification scheme (for example, `GeneralAudience` and `AgeGroups` are available classes with a set of subclasses that follow the existing taxonomies to classify the public).

⊙ *SuperClasses*: `Property`

⊙ *SubClasses*: `BroadcastMode`, `TargetAudience`.

▣ **Browse**

⊙ *Documentation*: Browse quality version of an `AudioVisualObject`

⊙ *SuperClasses*: `Version`

▣ **CDROM_Drive**

⊙ *Documentation*: CDROM Drive

⊙ *SuperClasses*: `Video_Drive`

⊙ *DisjointWith*: `1_2_Betacam_Drive`, `1_Drive`, `2_Drive`, `BetacamSP_Drive`, `BetaMax_Drive`, `D1_Drive`, `D2_Drive`, `D3_Drive`, `D5_Drive`, `D6_Drive`, `DigitalBetacam_Drive`, `DVD_Drive`, `SVHS_Drive`, `Umatic_Drive`, `VHS_Drive`, `Video8_Drive`.

⊙ *DomainOf*: `reads`

▣ **Dancer**

⊙ *Documentation*: A performer who dances.

⊙ *SuperClasses*: `Performer`

▣ **DigitalBetacam**

⊙ *Documentation*: Abstract class that represents the DigitalBetacam video format.

⊙ *SuperClasses*: `Video`

⊙ *DisjointWith*: `1"`, `2"`, `1/2"Betacam`, `BetacamSP`, `D1`, `D2`, `D3`, `D5`, `D6`, `BetaMax`, `DVCPPro`, `DVcam`, `S-VHS`, `U-Matic`, `Video8`, `VHS`, `DVD`.

⊙ *DomainOf*: `is-Read-by`

▣ **DigitalBetacam_Drive**

⊙ *Documentation*: DigitalBetacam Drive

⊙ *SuperClasses*: `Video_Drive`

⊙ *DisjointWith*: `1_2_Betacam_Drive`, `1_Drive`, `2_Drive`, `BetacamSP_Drive`, `BetaMax_Drive`, `CDROM_Drive`, `D1_Drive`, `D2_Drive`, `D3_Drive`, `D5_Drive`, `D6_Drive`, `DVD_Drive`, `SVHS_Drive`, `Umatic_Drive`, `VHS_Drive`, `Video8_Drive`.

⊙ *DomainOf*: `reads`

□ Director

- ⊙ *Documentation*: A supervisor; generally refers to the person responsible for all audience-visible components of a program, film, or show, whereas the producer is responsible for the financial and other behind-the-scenes aspects. A director's duties might also include casting, script editing, shot selection, shot composition and editing.
- ⊙ *SuperClasses*: ProductionPersonnel.

□ DVD_Drive

- ⊙ *Documentation*: DVD Drive
- ⊙ *SuperClasses*: Video_Drive
- ⊙ *DisjointWith*: 1_2_Betacam_Drive, 1_Drive, 2_Drive, BetacamSP_Drive, BetaMax_Drive, CDROM_Drive, D1_Drive, D2_Drive, D3_Drive, D5_Drive, D6_Drive, DigitalBetacam_Drive, SVHS_Drive, Umatic_Drive, VHS_Drive, Video8_Drive.
- ⊙ *DomainOf*: reads

□ D1

- ⊙ *Documentation*: Abstract class that represents the D1 video format.
- ⊙ *SuperClasses*: Video
- ⊙ *DisjointWith*: 1", 2", 1/2"Betacam, BetacamSP, DigitalBetacam, D2, D3, D5, D6, BetaMax, DVCPro, DVcam, S-VHS, U-Matic, Video8, VHS, DVD.
- ⊙ *DomainOf*: is-Read-by

□ D1_Drive

- ⊙ *Documentation*: D1 Drive
- ⊙ *SuperClasses*: Video_Drive
- ⊙ *DisjointWith*: 1_2_Betacam_Drive, 1_Drive, 2_Drive, BetacamSP_Drive, BetaMax_Drive, CDROM_Drive, D2_Drive, D3_Drive, D5_Drive, D6_Drive, DigitalBetacam_Drive, DVD_Drive, SVHS_Drive, Umatic_Drive, VHS_Drive, Video8_Drive.
- ⊙ *DomainOf*: reads

□ D2

- ⊙ *Documentation*: Abstract class that represents the D2 video format.
- ⊙ *SuperClasses*: Video
- ⊙ *DisjointWith*: 1", 2", 1/2"Betacam, BetacamSP, DigitalBetacam, D1, D3, D5, D6, BetaMax, DVCPro, DVcam, S-VHS, U-Matic, Video8, VHS, DVD.
- ⊙ *DomainOf*: is-Read-by

□ **D2_Drive**

- ⊙ *Documentation:* D2 Drive
- ⊙ *SuperClasses:* Video_Drive
- ⊙ *DisjointWith:* 1_2_Betacam_Drive, 1_Drive, 2_Drive, BetacamSP_Drive, BetaMax_Drive, CDRom_Drive, D1_Drive, D3_Drive, D5_Drive, D6_Drive, DigitalBetacam_Drive, DVD_Drive, SVHS_Drive, Umatic_Drive, VHS_Drive, Video8_Drive.
- ⊙ *DomainOf:* reads

□ **D3**

- ⊙ *Documentation:* Abstract class that represents the D3 video format.
- ⊙ *SuperClasses:* Video
- ⊙ *DisjointWith:* 1", 2", 1/2"Betacam, BetacamSP, DigitalBetacam, D1, D2, D5, D6, BetaMax, DVCPPro, DVcam, S-VHS, U-Matic, Video8, VHS, DVD.
- ⊙ *DomainOf:* is-Read-by

□ **D3_Drive**

- ⊙ *Documentation:* D3 Drive
- ⊙ *SuperClasses:* Video_Drive
- ⊙ *DisjointWith:* 1_2_Betacam_Drive, 1_Drive, 2_Drive, BetacamSP_Drive, BetaMax_Drive, CDRom_Drive, D1_Drive, D2_Drive, D5_Drive, D6_Drive, DigitalBetacam_Drive, DVD_Drive, SVHS_Drive, Umatic_Drive, VHS_Drive, Video8_Drive.
- ⊙ *DomainOf:* reads

□ **D5**

- ⊙ *Documentation:* Abstract class that represents the D5 video format.
- ⊙ *SuperClasses:* Video
- ⊙ *DisjointWith:* 1", 2", 1/2"Betacam, BetacamSP, DigitalBetacam, D1, D2, D3, D6, BetaMax, DVCPPro, DVcam, S-VHS, U-Matic, Video8, VHS, DVD.
- ⊙ *DomainOf:* is-Read-by

□ **D5_Drive**

- ⊙ *Documentation:* D5 Drive
- ⊙ *SuperClasses:* Video_Drive
- ⊙ *DisjointWith:* 1_2_Betacam_Drive, 1_Drive, 2_Drive, BetacamSP_Drive, BetaMax_Drive, CDRom_Drive, D1_Drive, D2_Drive, D3_Drive, D6_Drive, DigitalBetacam_Drive, DVD_Drive, SVHS_Drive, Umatic_Drive, VHS_Drive, Video8_Drive.
- ⊙ *DomainOf:* reads

□ **D6**

- ⊙ *Documentation*: Abstract class that represents the D6 video format.
- ⊙ *SuperClasses*: Video
- ⊙ *DisjointWith*: 1", 2", 1/2"Betacam, BetacamSP, DigitalBetacam, D1, D2, D3, D5, BetaMax, DVCPro, DVcam, S-VHS, U-Matic, Video8, VHS, DVD.
- ⊙ *DomainOf*: is-Read-by

□ **D6_Drive**

- ⊙ *Documentation*: D6 Drive
- ⊙ *SuperClasses*: Video_Drive
- ⊙ *DisjointWith*: 1_2_Betacam_Drive, 1_Drive, 2_Drive, BetacamSP_Drive, BetaMax_Drive, CDROM_Drive, D1_Drive, D2_Drive, vD3_Drive, D5_Drive, DigitalBetacam_Drive, DVD_Drive, SVHS_Drive, Umatic_Drive, VHS_Drive, Video8_Drive.
- ⊙ *DomainOf*: reads

□ **File**

- ⊙ *Documentation*: The File class is used to relate content available in an OnlineServer with an AudiovisualObject through the property has-file. The association is-availableFrom identifies the Files available from a Server.
- ⊙ *SuperClasses*: ManagedElement
- ⊙ *DomainOf*: fileID, is-availableFrom.

□ **Film_Drive**

- ⊙ *Documentation*: A MediaAccessDevice that is able to read film.
- ⊙ *SuperClasses*: MediaAccessDevice
- ⊙ *SubClasses*: 16mm_Drive, 35mm_Drive.
- ⊙ *DisjointWith*: Video_Drive
- ⊙ *DomainOf*: reads

□ **Genre**

- ⊙ *Documentation*: This dimension is used to classify programmes according to their content or subject. According to TVA:ContentCS, TVA:FormatCS, EBU:Escort2.4:Format, EBU:Escort2.4:-Content, DVB:EIT, PMeta:EDITORIAL_FORMAT_CODE and MPEG7:CreationInformation.Classification.-Genre. It is an abstract class.
- ⊙ *SuperClasses*: Property
- ⊙ *SubClasses*: NonFiction/Information, Drama/Fiction, Amusement/Entertainment/Hobbies, Music/Ballet/Dance/Art, Sports

□ Internet

- ⊙ *Documentation:* Internet quality version of an `AudioVisualObject`.
- ⊙ *SuperClasses:* `Version`

□ Interviewer

- ⊙ *Documentation:* A person who conducts an interview.
- ⊙ *SuperClasses:* `Participant`

□ InvitedGuest

- ⊙ *Documentation:* A person that participates in a programme as a guest.
- ⊙ *SuperClasses:* `Participant`

□ Journalist

- ⊙ *Documentation:* A person who gathers news and other journalistic material and writes or broadcasts it; the basic job in journalism.
- ⊙ *SuperClasses:* `Participant`

□ ManagedElement

- ⊙ *Documentation:* Management operations are to be performed over systems that make the archive operational. High level decisions will be based not only on the characteristics of the content but also on the hardware availability and its characteristics. The `ManagedElement` is used to describe manageable hardware or physical resources.
- ⊙ *SubClasses:* `File`, `MediaAccessDevice`, `NetworkLink`, `Network`, `PhysicalMedia`, `Server`, `Workstation`

□ MediaAccessDevice

- ⊙ *Documentation:* The `MediaAccessDevice` class tries to catch the characteristics and manageability of all types of media access devices. A `MediaAccessDevice` represents the ability to access one or more media and use this media to store and retrieve data. This class has a set of subclasses that concretise the type of media the device is able to read (e.g a 16mm film, a 1" tape, a Betamax tape, a Umatic tape, etc). This class can be directly mapped to the `CIM:Device:MediaAccessDevice` class. A set of properties from this CIM class were selected based on its importance concerning high level management decisions.
- ⊙ *SuperClasses:* `ManagedElement`
- ⊙ *SubClasses:* `FilmDrive`, `VideoDrive`
- ⊙ *DomainOf:* `lastCleaned`, `loadTime`, `maxAccessTime`, `mountCount-drive`, `name`, `needsCleaning`, `numberOfMediaSupported`, `reads`.

□ **MediaType**

- ⊙ *Documentation:* Is an abstract class used to classify **PhysicalMedia** based on the type of tape/film used to store the content.
- ⊙ *SuperClasses:* **Property**
- ⊙ *SubClasses:* **Film**, **Video**.
- ⊙ *DomainOf:* **is-Read-by**

□ **Musician**

- ⊙ *Documentation:* Someone who plays a musical instrument.
- ⊙ *SuperClasses:* **Performer**

□ **Narrator**

- ⊙ *Documentation:* A person who tells a story.
- ⊙ *SuperClasses:* **Participant**

□ **NearOnlineServer**

- ⊙ *Documentation:* This class implements the concept of a Near-On-Line Archive.
- ⊙ *SuperClasses:* **Server**
- ⊙ *DisjointWith:* **OnLineServer**

□ **Network**

- ⊙ *Documentation:* The archive is deployed in a media area network requiring, then, the identification of each subnetwork (the class **Network** in this ontology). From the point of view of the high level management, this information is not directly relevant but will be required by the system for reasoning on the network load on the link that connects a **Workstation** and a **Server**.
- ⊙ *SuperClasses:* **ManagedElement**
- ⊙ *DomainOf:* **name**, **NetworkID**.

□ **NetworkLink**

- ⊙ *Documentation:* The **NetworkLink** class is a simplified version of the CIM specification for characterising Network Connections. From a Business point of view, the manager is not interested in details of the technology but only on the aspects that enable an efficient management of the resources. This class re-uses concepts from the **CIM:Network:ProtocolEndPoints** class, **CIM:Core:ActiveConnections** association, **CIM:Network:NetworkPipe** class and from some specific classes concerning communications technologies used.
- ⊙ *SuperClasses:* **ManagedElement**
- ⊙ *DomainOf:* **activeBandwidth**, **connects**, **linkID**, **reservedBandwidth**, **name**, **status**, **total-Bandwidth**.

▣ **OnLineServer**

⊙ *Documentation:* The **OnLineServer** implements the concept of an On-Line Archive. A set of properties enables the identification of the location (**is-ConnectedTo**), characterisation of the storage capacity (**TotalManagedSpace** and **RemainingManagedSpace**) as well as the definition of some management requirements like **LowSpaceWarningThreshold**. The **OnlineServer** maps to the **CIM:Device:StoragePool** class.

⊙ *SuperClasses:* **Server**

⊙ *DisjointWith:* **NearOnLineServer**

⊙ *DomainOf:* **is-ConnectedTo**, **LowSpaceWarningThreshold**, **RemainingManagedSpace**, **TotalManagedSpace**.

▣ **OtherMedias**

⊙ *Documentation:* The Class **OtherMedias** is used to associate other medias (e.g. keyframes, audio tracks) to a programme. Although they have relative importance they are not the main object of management.

⊙ *SuperClasses:* **AudioVisualObject**

⊙ *DisjointWith:* **Programme**, **Rushes**.

▣ **Participant**

⊙ *Documentation:* Someone that participates in a Programme.

⊙ *SuperClasses:* **Person**

⊙ *SubClasses:* **Interviewer**, **Journalist**, **Performer**, **InvitedGuest**, **Narrator**.

⊙ *DomainOf:* **participates-In**.

▣ **Performer**

⊙ *Documentation:* An entertainer who performs a dramatic or musical work for audience.

⊙ *SuperClasses:* **Participant**

⊙ *SuperClasses:* **Actor**, **Dancer**, **Musician**, **Singer**.

▣ **Person**

⊙ *Documentation:* The last part of the ontology contains the concepts that enable a **Person** to be associated with a **Programme** based on its role: technical staff can be identified through the class **ProductionPersonnel** (which can be further classified e.g as a **Director** or **ScriptWriter**) while a participant in the programme is identified through the **Participant** class (which can also be specialised e.g as an **Interviewer** or an **InvitedGuest**). This class can be mapped to the **TVA:RoleCS** and **MPEG7:CS.RoleCS**.

⊙ *SubClasses:* **ProductionPersonnel**, **Participant**.

- ⊙ *DomainOf*: **name**.

▣ **PlayCount**

- ⊙ *Documentation*: Indicates restriction on the number of plays a piece of content is allowed.
- ⊙ *SuperClasses*: **Rights**
- ⊙ *DomainOf*: **maxCounts**, **nrCounts**.

▣ **PlayForever**

- ⊙ *Documentation*: Indicates no restriction on use of a piece of content.
- ⊙ *SuperClasses*: **Rights**

▣ **PlayForPeriod**

- ⊙ *Documentation*: Indicates some restriction on the period of use for a piece of content.
- ⊙ *SuperClasses*: **Rights**
- ⊙ *DomainOf*: **beginPeriod**, **endPeriod**

▣ **Pos-Producer**

- ⊙ *Documentation*: A person responsible for special features editing.
- ⊙ *SuperClasses*: **ProductionPersonnel**.

▣ **Producer**

- ⊙ *Documentation*: The manager of an event, show, or other work, usually the individual in charge of finance, personnel and other non-artistic aspects in the development of commercials, plays, movies and other works.
- ⊙ *SuperClasses*: **ProductionPersonnel**.

▣ **ProductionPersonnel**

- ⊙ *Documentation*: Technical staff associated with the making of a programme.
- ⊙ *SuperClasses*: **Person**
- ⊙ *SubClasses*: **Director**, **Producer**, **Pos-Producer**, **ScriptWriter**.

▣ **PhysicalMedia**

- ⊙ *Documentation*: The **PhysicalMedia** class represents any type of documentation or storage medium, such as tapes, CDROMs, etc. This class is typically used to locate and manage Removable Media. Maps to CIM:Physical:PhysicalMedia.
- ⊙ *SuperClasses*: **ManagedElement**
- ⊙ *DomainOf*: **has-mediaType**, **label**, **maxMounts**, **mountCount**, **timeOfLastMount**, **totalMount-Time**.

▣ Programme

- ⊙ *Documentation:* A **Programme** is an audiovisual work that has been defined and created by a commissioning decision. This concept maps to P_Meta definitions.
- ⊙ *SuperClasses:* **AudioVisualObject**
- ⊙ *DisjointWith:* **OtherMedias**, **Rushes**.
- ⊙ *DomainOf:* **broadcastDate**, **has-audienceShare**, **has-award**, **has-broadcastMode**, **has-genre**, **has-participant**, **has-rights**, **has-targetAudience**, **has-team**.

▣ Property

- ⊙ *Documentation:* **AudioVisualObjects** will have a set of properties that provide additional information to characterise content. The main concepts are grouped under this class.
- ⊙ *SubClasses:* **Genre**, **BroadcastProperties**, **Award**, **Rights**, **Version**, **MediaType**.

▣ Rights

- ⊙ *Documentation:* The purchase type (**PlayForEver**, **PlayforPeriod**, **PlayCounts**) can help the manager to signal content that should be re-used due to the fact that the owned rights are expiring. Defines quantity units to further qualify a purchase type in ‘days’, ‘months’ or ‘years’ for a period of time and ‘plays’ for a number of plays. The hierarchy defined for the **Rights** class follows the classification scheme of the TV-Anytime standard (TVA:PurchaseTypeCS).
- ⊙ *SuperClasses:* **Property**
- ⊙ *SubClasses:* **PlayForEver**, **PlayForPeriod**, **PlayCounts**.

▣ Rushes

- ⊙ *Documentation:* This concept represents all type of media that comes directly from the camera without editing.
- ⊙ *SuperClasses:* **AudioVisualObject**
- ⊙ *DisjointWith:* **OtherMedias**, **Programme**.

▣ ScriptWriter

- ⊙ *Documentation:* A person who writes scripts for plays or movies or broadcast dramas.
- ⊙ *SuperClasses:* **ProductionPersonnel**.

▣ Server

- ⊙ *Documentation:* The **Server** class catches the characteristics of the Essence archives as defined in Section 5.2.2: the On-Line Archive (**OnlineServer**) and the Near-On-Line Archive (**NearOnlineServer**).
- ⊙ *SuperClasses:* **ManagedElement**

- ⊙ *SubClasses*: OnLineServer, NearOnLineServer
- ⊙ *DomainOf*: name.

□ **Singer**

- ⊙ *Documentation*: A person who sings.
- ⊙ *SuperClasses*: Performer

□ **SVHS**

- ⊙ *Documentation*: Abstract class that represents the SVHS video format.
- ⊙ *SuperClasses*: Video
- ⊙ *DisjointWith*: 1", 2", 1/2"Betacam, BetacamSP, DigitalBetacam, D1, D2, D3, D5, D6, BetaMax, DVCPro, DVcam, U-Matic, Video8, VHS, DVD.
- ⊙ *DomainOf*: is-Read-by

□ **SVHS_Drive**

- ⊙ *Documentation*: SVHS Drive
- ⊙ *SuperClasses*: Video_Drive
- ⊙ *DisjointWith*: 1_2_Betacam_Drive, 1_Drive, 2_Drive, BetacamSP_Drive, BetaMax_Drive, CDROM_Drive, D1_Drive, D2_Drive, D3_Drive, D5_Drive, D6_Drive, DigitalBetacam_Drive, DVD_Drive, Umatic_Drive, VHS_Drive, Video8_Drive.
- ⊙ *DomainOf*: reads

□ **U-matic**

- ⊙ *Documentation*: Abstract class that represents the U-matic video format.
- ⊙ *SuperClasses*: Video
- ⊙ *DisjointWith*: 1", 2", 1/2"Betacam, BetacamSP, DigitalBetacam, D1, D2, D3, D5, D6, BetaMax, DVCPro, DVcam, S-VHS, Video8, VHS, DVD.
- ⊙ *DomainOf*: is-Read-by

□ **Umatic_Drive**

- ⊙ *Documentation*: Umatic Drive
- ⊙ *SuperClasses*: Video_Drive
- ⊙ *DisjointWith*: 1_2_Betacam_Drive, 1_Drive, 2_Drive, BetacamSP_Drive, BetaMax_Drive, CDROM_Drive, D1_Drive, D2_Drive, D3_Drive, D5_Drive, D6_Drive, DigitalBetacam_Drive, DVD_Drive, SVHS_Drive, VHS_Drive, Video8_Drive.
- ⊙ *DomainOf*: reads

□ **Version**

⊙ *Documentation:* The architecture proposed in this thesis defines a set of different archives which support different content qualities (high quality, browse quality, internet quality). The class **Version** reflects this classification and might be used, together with information concerning network load, to optimise resources (see Example 4 in 7.3.1). The slot **has-copy** enables the association of the classes **AudioVisualObject** and **Property:Version**.

⊙ *SuperClasses:* **Property**

⊙ *SubClasses:* **Broadcast**, **Browse**, **Internet**

⊙ *DomainOf:* **has-file**, **ID**, **is-stored-in**.

□ **VHS**

⊙ *Documentation:* Abstract class that represents the VHS video format.

⊙ *SuperClasses:* **Video**

⊙ *DisjointWith:* **1"**, **2"**, **1/2"Betacam**, **BetacamSP**, **DigitalBetacam**, **D1**, **D2**, **D3**, **D5**, **D6**, **BetaMax**, **DVCPPro**, **DVcam**, **U-Matic**, **Video8**, **S-VHS**, **DVD**.

⊙ *DomainOf:* **is-Read-by**

□ **VHS_Drive**

⊙ *Documentation:* VHS Drive

⊙ *SuperClasses:* **Video_Drive**

⊙ *DisjointWith:* **1.2.Betacam_Drive**, **1_Drive**, **2_Drive**, **BetacamSP_Drive**, **BetaMax_Drive**, **CDROM_Drive**, **D1_Drive**, **D2_Drive**, **D3_Drive**, **D5_Drive**, **D6_Drive**, **DigitalBetacam_Drive**, **DVD_Drive**, **SVHS_Drive**, **Umatic_Drive**, **Video8_Drive**.

⊙ *DomainOf:* **reads**

□ **Video_Drive**

⊙ *Documentation:* A **MediaAccessDevice** that is able to read video tapes.

⊙ *SuperClasses:* **MediaAccessDevice**

⊙ *SubClasses:* **1.2.Betacam_Drive**, **1_Drive**, **2_Drive**, **BetacamSP_Drive**, **BetaMax_Drive**, **CDROM_Drive**, **D1_Drive**, **D2_Drive**, **D3_Drive**, **D5_Drive**, **D6_Drive**, **DigitalBetacam_Drive**, **DVD_Drive**, **SVHS_Drive**, **Umatic_Drive**, **VHS_Drive**, **Video8_Drive**.

⊙ *DisjointWith:* **Fim_Drive**

⊙ *DomainOf:* **reads**

□ **Video8**

⊙ *Documentation:* Abstract class that represents the Video8 video format.

⊙ *SuperClasses:* **Video**

⊙ *DisjointWith:* **1"**, **2"**, **1/2"Betacam**, **BetacamSP**, **DigitalBetacam**, **D1**, **D2**, **D3**, **D5**, **D6**, **BetaMax**, **DVCPPro**, **DVcam**, **U-Matic**, **VHS**, **S-VHS**, **DVD**.

⊙ *DomainOf*: is-Read-by

▣ **Video8_Drive**

⊙ *Documentation*: Video8 Drive

⊙ *SuperClasses*: Video_Drive

⊙ *DisjointWith*: 1_2_Betacam_Drive, 1_Drive, 2_Drive, BetacamSP_Drive, BetaMax_Drive, CDROM_Drive, D1_Drive, D2_Drive, D3_Drive, D5_Drive, D6_Drive, DigitalBetacam_Drive, DVD_Drive, SVHS_Drive, Umatic_Drive, VHS_Drive.

⊙ *DomainOf*: reads

▣ **Workstation**

⊙ *Documentation*: Activities like annotation, browsing and editing are performed in a Workstation that is-ConnectedTo an instance of a Network

⊙ *SuperClasses*: ManagedElement

⊙ *DomainOf*: is-ConnectedTo, name.

▣ **1"**

⊙ *Documentation*: Abstract class that represents the 1" video format.

⊙ *SuperClasses*: Video

⊙ *DisjointWith*: 2", 1/2"Betacam, BetacamSP, BetaMax, D1, D2, D3, D5, D6, DigitalBetacam, DVCPPro, DVcam, S-VHS, U-Matic, Video8, VHS, DVD.

⊙ *DomainOf*: is-Read-by

▣ **2"**

⊙ *Documentation*: Abstract class that represents the 2" video format.

⊙ *SuperClasses*: Video

⊙ *DisjointWith*: 1", 1/2"Betacam, BetacamSP, BetaMax, D1, D2, D3, D5, D6, DigitalBetacam, DVCPPro, DVcam, S-VHS, U-Matic, Video8, VHS, DVD.

⊙ *DomainOf*: is-Read-by

▣ **16mm_Drive**

⊙ *Documentation*: Equipment able to read 16mm film.

⊙ *SuperClasses*: Film_Drive

⊙ *DomainOf*: reads

▣ **35mm_Drive**

⊙ *Documentation*: Equipment able to read 35mm film.

⊙ *SuperClasses*: Film_Drive

⊙ *DomainOf*: reads

□ 1/2"Betacam"

⊙ *Documentation*: Abstract class that represents the 1/2" Betacam video format.

⊙ *SuperClasses*: Video

⊙ *DisjointWith*: 1", 1/2"Betacam, BetacamSP, BetaMax, D1, D2, D3, D5, D6, DigitalBetacam, DVCPPro, DVcam, S-VHS, U-Matic, Video8, VHS, DVD.

⊙ *DomainOf*: is-Read-by

□ 1.2.Betacam_Drive

⊙ *Documentation*: 1/2" Betacam_Drive

⊙ *SuperClasses*: Video_Drive

⊙ *DisjointWith*: 1_Drive, 2_Drive, BetacamSP_Drive, BetaMax_Drive, CDRom_Drive, D1_Drive, D2_Drive, D3_Drive, D5_Drive, D6_Drive, DigitalBetacam_Drive, DVD_Drive, SVHS_Drive, Umatic_Drive, VHS_Drive, Video8_Drive.

⊙ *DomainOf*: reads

□ 1_Drive

⊙ *Documentation*: 1" Drive

⊙ *SuperClasses*: Video_Drive

⊙ *DisjointWith*: 1.2_Betacam_Drive, 2_Drive, BetacamSP_Drive, BetaMax_Drive, CDRom_Drive, D1_Drive, D2_Drive, D3_Drive, D5_Drive, D6_Drive, DigitalBetacam_Drive, DVD_Drive, SVHS_Drive, Umatic_Drive, VHS_Drive, Video8_Drive.

⊙ *DomainOf*: reads

□ 2_Drive

⊙ *Documentation*: 2" Drive

⊙ *SuperClasses*: Video_Drive

⊙ *DisjointWith*: 1.2_Betacam_Drive, 1_Drive, BetacamSP_Drive, BetaMax_Drive, CDRom_Drive, D1_Drive, D2_Drive, D3_Drive, D5_Drive, D6_Drive, DigitalBetacam_Drive, DVD_Drive, SVHS_Drive, Umatic_Drive, VHS_Drive, Video8_Drive.

⊙ *DomainOf*: reads

A.2 Property Documentation

□ activeBandwidth

⊙ *Documentation:* Active/available bandwidth for a Network link in kilobits per second. Maps to CIM

⊙ *Domain:* NetworkLink

▣ **beginPeriod**

⊙ *Documentation:* Enables the identification of the period that a piece of content can be used without breaking the legal purchase model. This property identifies the starting date.

⊙ *Domain:* PlayforPeriod

▣ **broadcastDate**

⊙ *Documentation:* Date when a programme was broadcasted.

⊙ *Domain:* Programme

▣ **connects**

⊙ *Documentation:* Indicates a connection between two Networks

⊙ *Domain:* NetworkLink

⊙ *Range:* Network

▣ **endPeriod**

⊙ *Documentation:* Enables the identification of the period that a piece of content can be used without breaking the legal purchase model. This property identifies the ending date.

⊙ *Domain:* PlayforPeriod

▣ **fileID**

⊙ *Documentation:* Unique identifier of a file available from an OnLineServer.

⊙ *Domain:* File

▣ **has-audienceShare**

⊙ *Documentation:* The share of a Programme had when broadcasted.

⊙ *Domain:* Programme

▣ **has-associatedMedia**

⊙ *Documentation:* Associates two pieces of Media.

⊙ *Domain:* AudioVisualObject

⊙ *Range:* AudioVisualObject

▣ **has-award**

⊙ *Documentation:* Associates a Programme with a list of awards that it has won or has been

nominated to.

- ◉ *Domain:* Programme
- ◉ *Range:* Award

▣ **has-broadcastMode**

- ◉ *Documentation:* Identifies if a Programme was transmitted live or deferred.
- ◉ *Domain:* Programme
- ◉ *Range:* BroadcastMode

▣ **has-copy**

- ◉ *Documentation:* Identifies an instance of an AudioVisualObject with a quality version.
- ◉ *Domain:* AudioVisualObject
- ◉ *Range:* Version

▣ **has-file**

- ◉ *Documentation:* Associates a version of an AudioVisualObject to a File available from an OnLineServer.
- ◉ *Domain:* Version
- ◉ *Range:* File

▣ **has-genre**

- ◉ *Documentation:* Identifies the genre of an AudioVisualObject
- ◉ *Domain:* Programme
- ◉ *Range:* Genre

▣ **has-mediaType**

- ◉ *Documentation:* Identifies a type of support.
- ◉ *Domain:* PhysicalMedia
- ◉ *Range:* MediaType

▣ **has-participant**

- ◉ *Documentation:* Identifies a person participating in a Programme
- ◉ *Domain:* Programme
- ◉ *Range:* Participant
- ◉ *InverseOf:* participates-In

▣ **has-rights**

- ◉ *Documentation:* Used to identify the type of restrictions on use of an AudioVisualObject

- ◉ *Domain:* AudioVisualObject

- ◉ *Range:* Rights

▣ **has-targetAudience**

- ◉ *Documentation:* The type of audience a programme is directed to.

- ◉ *Domain:* Programme

- ◉ *Range:* TargetAudience

▣ **has-team**

- ◉ *Documentation:* Used to list people involved in making a Programme

- ◉ *Domain:* Programme

- ◉ *Range:* ProductionPersonnel

▣ **is-availableFrom**

- ◉ *Documentation:* Associates a File to the OnLineServer it is available from.

- ◉ *Domain:* File

- ◉ *Range:* OnLineServer

▣ **is-ConnectedTo**

- ◉ *Documentation:* Identifies the Network an equipment is connected to.

- ◉ *Domain:* Server, Workstation

- ◉ *Range:* Network

▣ **is-Read-by**

- ◉ *Documentation:* Identifies the type of drive that is capable of reading a media type.

- ◉ *Domain:* MediaType

- ◉ *Range:* MediaAccessDevice

- ◉ *InverseOf:* reads

▣ **is-Stored-in**

- ◉ *Documentation:* Identifies the tape or film where an instance of a AudiovisualObject is stored in.

- ◉ *Domain:* Version

- ◉ *Range:* PhysicalMedia

▣ **label**

- ◉ *Documentation:* Unique identifier of a tape or film.

- ◉ *Domain:* PhysicalMedia

▣ lastCleaned

- ◉ *Documentation:* The last time a drive was cleaned.
- ◉ *Domain:* `MediaAccessDevice`

▣ linkID

- ◉ *Documentation:* Unique identifier of a Network Link.
- ◉ *Domain:* `NetworkLink`

▣ loadTime

- ◉ *Documentation:* Time in milliseconds from being able to read or write a Media to its ‘unload’. For example, for DiskDrives, this is the interval between a disk spinning at nominal speeds and a disk not spinning. For Tape Drives, this is the time for a Media to go from its BOT to being fully ejected and accessible to a PickerElement or human operator. Maps to `CIM:Device.MediaAccessDevice.loadTime`.
- ◉ *Domain:* `MediaAccessDevice`

▣ lowSpaceWarningThreshold

- ◉ *Documentation:* Used to indicate the the amount of free space is under a pre-dined value. Maps to `CIM:StoragePool.lowSpaceWarningThreshold`.
- ◉ *Domain:* `OnLineServer`

▣ participates-in

- ◉ *Documentation:* Identifies the `Programme` where a person participates in.
- ◉ *Domain:* `Participant`
- ◉ *Range:* `Programme`
- ◉ *InverseOf:* `has-participant`

▣ maxAccessTime

- ◉ *Documentation:* The sustained data transfer rate in KB/sec that the Device can read from and write to a Media. This is a sustained, raw data rate. Maximum rates or rates assuming compression should not be reported in this property. Maps to `CIM:Device.MediaAccessDevice.-MaxAccessTime`.
- ◉ *Domain:* `MediaAccessDevice`

▣ maxCounts

- ◉ *Documentation:* the maximum number of times a piece of content can be used without breaking legal rights.

⊙ *Domain:* PlayCounts

▣ **maxMounts**

⊙ *Documentation:* This is the number of times that Media can be mounted without endanger the physical support .

⊙ *Domain:* PhysicalMedia

▣ **mountCount**

⊙ *Documentation:* This is the number of times that Media have been mounted for data transfer.

⊙ *Domain:* PhysicalMedia

▣ **name**

⊙ *Documentation:* enables the identification of an object (person, device, etc) using a user friendly identifier.

⊙ *Domain:* Person, Server, Network, MediaAccessDevice, Genre, Rights NetworkLink, Workstation

▣ **needCleaning**

⊙ *Documentation:* Boolean indicating that the MediaAccessDevice needs cleaning. Maps to CIM:- Device.MediaAccessDevice.NeedsCleaning.

⊙ *Domain:* MediaAccessDevice

▣ **nrCounts**

⊙ *Documentation:* the number of times a piece of content was used. Is used when the purchase option is based on a number of allowed re-used.

⊙ *Domain:* PlayCounts

▣ **networkID**

⊙ *Documentation:* unique identifier of a network

⊙ *Domain:* Network

▣ **numberOfMediaSupported**

⊙ *Documentation:* When the MediaAccessDevice supports multiple individual Media, this property defines the maximum number which can be supported or inserted. Maps to CIM:- MediaAccessDevice.NumberOfMediaSupported.

⊙ *Domain:* MediaAccessDevice

▣ **productionDate**

⊙ *Documentation:* The date or time period when the programme was produced.

⊙ *Domain:* `AudioVisualObject`

▣ **reads**

- ⊙ *Documentation:* identifies the media type a driver (`MediaAccessDevice`) is capable of reading.
- ⊙ *Domain:* `MediaAccessDevice`
- ⊙ *Range:* `MediaType`
- ⊙ *InverseOf:* `is-Read-by`

▣ **remainingManagedSpace**

- ⊙ *Documentation:* The remaining usable capacity. Maps directly to the equivalent CIM property.
- ⊙ *Domain:* `OnLineServer`

▣ **reservedBandwidth**

- ⊙ *Documentation:* Reserved bandwidth (in kilobits per second) in a network connection due to future editorial needs. Equivalent to `CIM:MPLS_tunnel:ReservedBandwidth`
- ⊙ *Domain:* `NetworkLink`

▣ **status**

- ⊙ *Documentation:* Indicates if the link is operational (1) or not (0). Equivalent to `CIM:-Network:MPLSTunnel:Established`. Overrides `OperatingStatus` from `CIM:ManagedElement:-ManagedSystemElement`
- ⊙ *Domain:* `NetworkLink`

▣ **synopsis**

- ⊙ *Documentation:* A textual description of an `AudioVisualObject`.
- ⊙ *Domain:* `AudioVisualObject`

▣ **timeOfLastAccess**

- ⊙ *Documentation:* Last time a piece of content was accessed.
- ⊙ *Domain:* `AudioVisualObject`

▣ **timeOfLastMount**

- ⊙ *Documentation:* The date and time that the Media was last mounted. Maps to `CIM:PhysicalMedia.timeOfLastMount`.
- ⊙ *Domain:* `PhysicalMedia`

▣ **title**

- ⊙ *Documentation:* The title of an `AudioVisualObject`.

⊙ *Domain:* AudioVisualObject

▣ **totalBandwidth**

⊙ *Documentation:* The **totalBandwidth** property denotes the complete bandwidth (in kilobits per second). Equivalent to **CIM:Network:MPLS:Bandwidth**.

⊙ *Domain:* NetworkLink

▣ **totalManagedSpace**

⊙ *Documentation:* The total amount of capacity usable. Maps directly to the CIM equivalent property.

⊙ *Domain:* OnLineServer

▣ **totalMountTime**

⊙ *Documentation:* The total time (in seconds) that the Media has been mounted for data transfer or to clean a Drive. Maps to **CIM:PhysicalMedia.totalMountTime**

⊙ *Domain:* PhysicalMedia

Appendix B

VIDION User Interfaces

This Appendix provides some examples of the user interfaces of the VIDION system. The screens presented are the result of a design effort developed by the company that took the research results for commercial exploitation. These examples are not intended to provide an exhaustive description of the different applications and of their functionalities but only to present the final graphical look resulting from an effort to convert a research result into a commercial product.

The first two pictures (Figure B.1 and Figure B.2) illustrate some functionalities available in the annotation application. The first one presents the main screen of a **Programme** annotation and some of the descriptor of the VIDION DS. The second one presents some of the technical information used to describe video material.

Figure B.3 depicts the result of a search operation of a News/Current Affairs **Programme** while the next one (Figure B.4) shows the screen used to collect the selected results.

Two examples of the Editing Application are presented in Figures B.5 and B.6. A list of items that might be used to create a new clip is available on the right hand side of Figure B.5. The following screen is used to preview the final result of the editing operation.

The Internet version of the Searching Application provides fewer functionalities than the one used in house as illustrated in Figure B.7

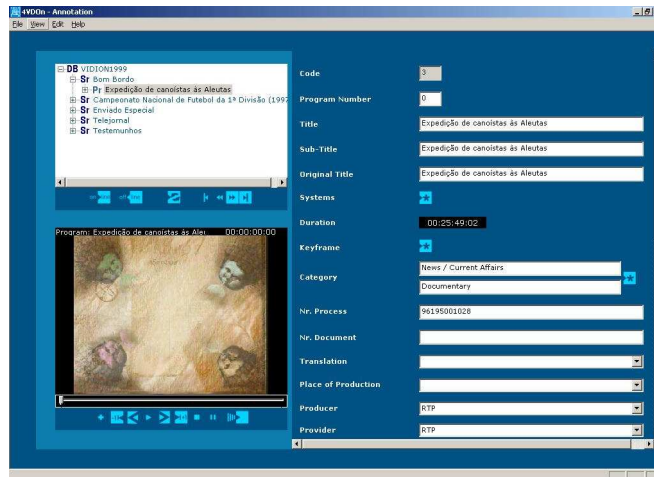


Figure B.1: View 1 of the Annotation Application

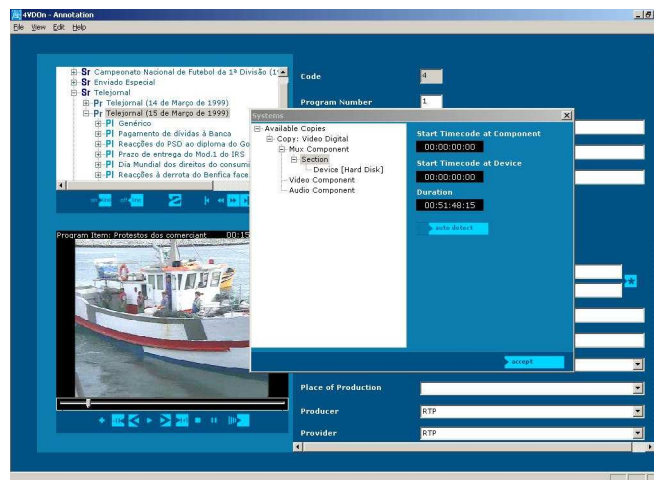


Figure B.2: View 2 of the Annotation Application

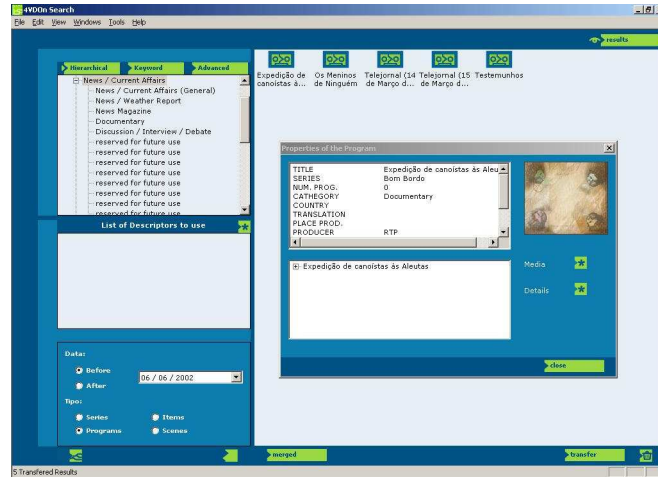


Figure B.3: View 1 of the Searching Application

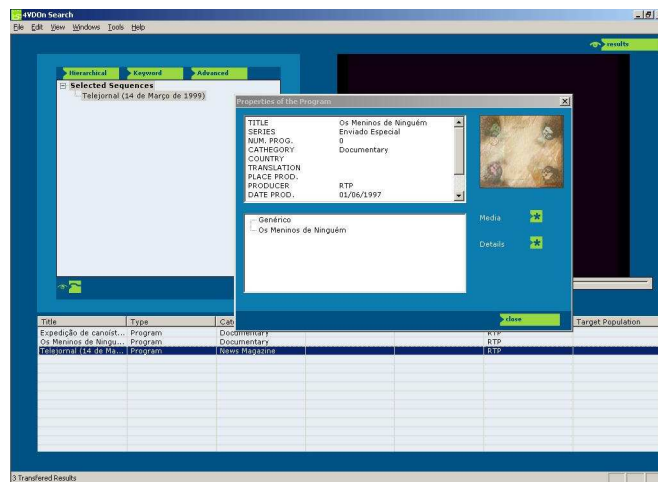


Figure B.4: View 2 of the Searching Application

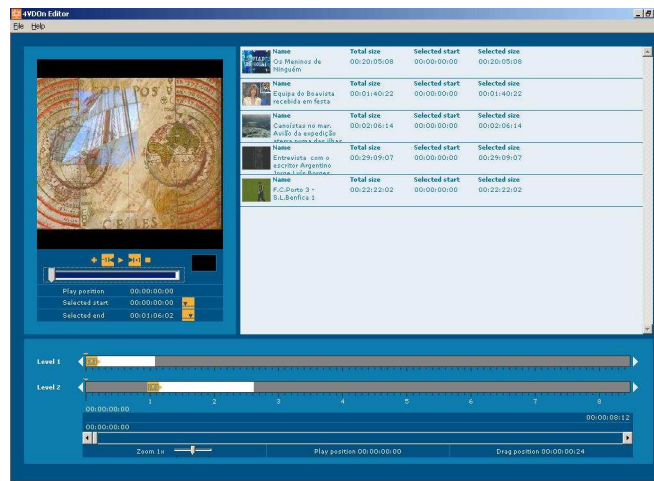


Figure B.5: View 1 of the Editing Application

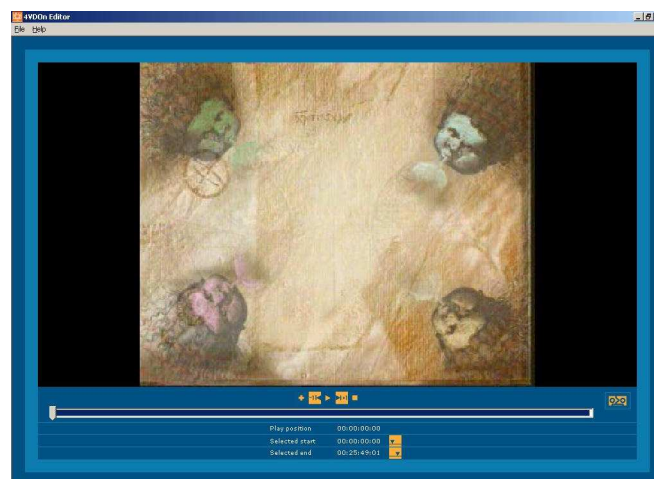


Figure B.6: View 2 of the Editing Application



Figure B.7: View of the Internet Searching Application

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